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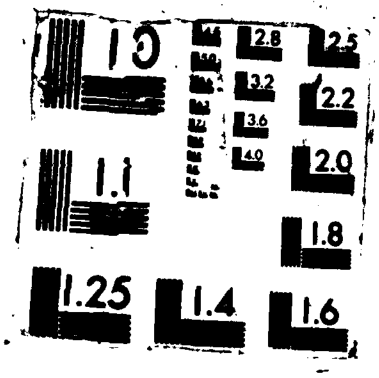
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CLOUD CLIMATOLOGY DERIVED FROM THE AFGWC 3D-NEPHANALYSIS FOR JANUARY AND JULY 1979

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Cloud climatologies of the Northern Hemisphere have been developed utilizing the AFGWC 3D-Nephanalysis (3DNEPH) cloud data base for January and July 1979. The vertical resolution of the 3DNEPH was reduced from 15 layers to 3 low, middle, and high (LMH) cloud layers. The horizontal grid points were mapped to the Nimbus-7 ERB/STA LAT/LON grid system to facilitate data comparison. Valid analysis times (Greenwich) were converted to local times. Zonal average total cloudiness correlates well with observed large-scale features for both months. The 3DNEPH compares reasonably well with other climatologies in the zonal average case except near the poles in the wintertime hemisphere. In this region, the 3DNEPH analysis overestimates the amount of midlevel cloudiness. This is thought to be caused by a lack of surface observations in the polar region, which may result in the infrared cloud processor misinterpreting cold snow-covered surfaces as clouds. Hemispherical plots of LMH and total cloud fields on a monthly mean scale are also presented.

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1. INTRODUCTION

Clouds have long been a major focus of research in the study of the atmosphere and its constituents. The cloud climatology compiled by London (1957) over 30 years ago, from surface observations that are now over 40 years old, is still the most widely used cloud climatology. Although many cloud climatologies exist (see Hughes, 1984), few, if any, provide detailed information about the vertical structure of a cloudy atmosphere or include diurnal effects of cloudiness. Many climatologies contain monthly, seasonal, or annual values on a zonally averaged scale (London, 1957; Oort and Rasmusson, 1971; Miller and Feddes, 1971). Unfortunately, no updated and comprehensive global climatology has been available since London's initial effort up to the present. The inadequacy of the currently available cloud climatologies has been recognized by the World Meteorological Organization and the International Association of Meteorology and Atmospheric Physics (WMO:IAMAP) (Schiffer, 1982). WMO:IAMAP established the International Satellite Cloud Climatology Project (ISCCP), whose main objective is to provide a five-year global cloud climatology based on satellite measurements. A number of other climate-related studies have been identified by the Global Atmospheric Research Program (GARP, 1978) as requiring input cloud information. These are:

(1) Climate diagnostic and climate monitoring programs.

(2) Studies of the dependence of climate on clouds.

(3) Studies of cloudiness and the earth radiation budget.

(4) Studies of the parameterization of cloud formation and cloud radiative processes.

The Air Weather Service high resolution 3DNEPH cloud analysis is the only operational cloud analysis program that uses both conventional and satellite information, and appears to be an ideal cloud data base for the development of a global cloud climatology. Gordon et al. (1984) have utilized the 3DNEPH analysis of monthly mean cloud fields as input into a cloud-radiation model. Hughes and Henderson-Sellers (1985) have compiled a total cloud climatology for 1979, and Henderson-Sellers (1986) has computed a layered cloud data base for 2 months in the same year. They used a compressed version of the 3DNEPH data set on both spatial and temporal scales to obtain the cloud fields. The importance of a comprehensive cloud data base on a global scale for comparison to the cloud fields derived from ISCCP cannot be overemphasized. Although this study focused on data archived before the start of the ISCCP, more current cloud data is available from the AFGWC RTNEPH data analysis that, when compared with the ISCCP product, may provide some insights into the cloud information that is required for climate modeling and analysis.

In this report we outline the methodology used to derive a cloud climatology from the 3DNEPH data archives. In Section 2 we describe the 3DNEPH data analysis and, in Section 3, the technique used to produce low, middle, and high cloud fields is discussed. A comparison of the 3DNEPH cloud climatologies with other available cloud data sets is also included.

2. 3DNEPH DATA BASE

The AFGWC (Air Force Global Weather Central) automated cloud analysis has been operational since early 1970. The model, which is also known as the 3DNEPH, integrates satellite and conventional cloud information to produce a high resolution global cloud analysis.

The horizontal resolution of the 3DNEPH is approximately 44 km at 60° latitude. The hemispheric grid consists of 262,144 grid points. To facilitate computer processing, the hemispheric grid is divided into 64 (8x8) 3DNEPH boxes. Each 3DNEPH box contains 4096 (64x64) grid points as shown in Fig. 1.

The vertical grid consists of 15 layers of variable thickness, which extend from the surface to 17 km, as illustrated in Table 1. The first six layers are AGL (above ground level) layers, while the remaining layers are MSL (mean sea level) layers. At grid points above sea level, some of the MSL layers may be partially or completely filled with terrain and/or AGL layers.

The valid time of the 3DNEPH analysis is 00Z plus every three hours. The run time of the 3DNEPH is approximately one hour and 20 minutes after the valid time of the analysis. The delay in the running of the 3DNEPH ensures that a majority of the conventional reports, within a valid time of the 3DNEPH, are available for processing into the 3DNEPH analysis.

In the normal configuration, visual and infrared imagery data from the morning and noon sun-synchronous polar orbiting DMSP (Defense Meteorological Satellite Program) satellites are used in the 3DNEPH analysis. The satellite data consist of visual and infrared daytime

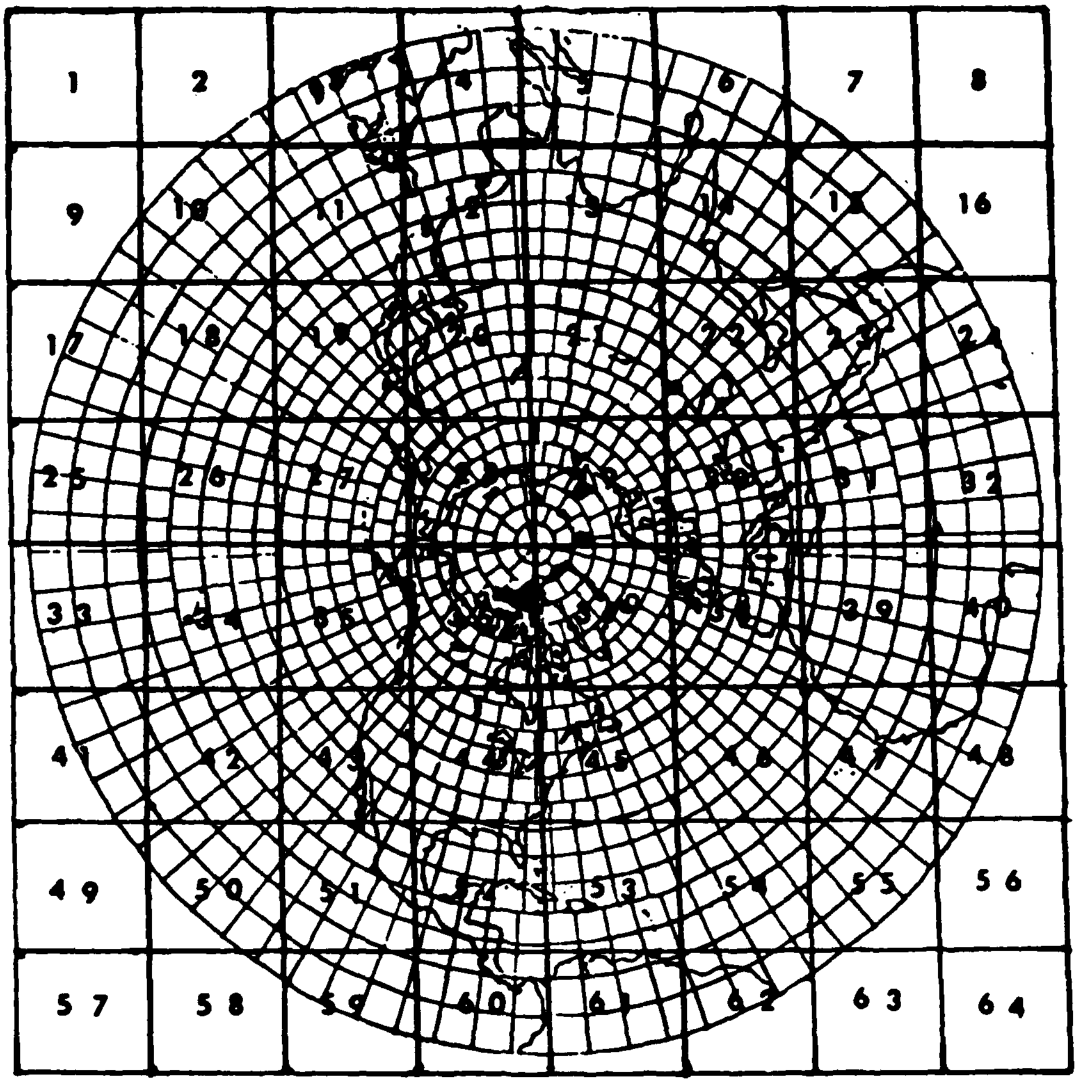

Fig. 1 64 3DNEPH boxes (large rectangular boxes) and the Nimbus-7 TA boxes (small concentric boxes).

Table 1 Layer heights and thicknesses of the 3DNEPH grid.

LAYER	Height ft (m)	Pressure Level mb	Thickness ft (m)
	Surface		
1			150 (46)
	150 (46) AGL		
2			150 (46)
	300 (91) AGL		
3			300 (92)
	600 (183) AGL		
4			400 (122)
	1000 (305) AGL		
5			1000 (305)
	2000 (610) AGL		
6			1500 (457)
	3500 (1067) AGL/MSL		
7			1500 (457)
	5000 (1524) MSL	850	
8			1500 (457)
	6500 (1981) MSL	800	
9			3500 (1067)
	10000 (3048) MSL	700	
10			4000 (1219)
	14000 (4267) MSL	600	
11			4000 (1219)
	18000 (5486) MSL	500	
12			4000 (1219)
	22000 (6706) MSL	430	
13			4000 (1219)
	26000 (7925) MSL	360	
14			9000 (2743)
	35000 (10668) MSL	240	
15			20000 (6096)
	55000 (16764) MSL	100	

imagery and infrared nighttime imagery. The imagery from the DMSP satellite is preprocessed and stored in the SGDB (Satellite Global Data Base). The resolution of this data base is approximately 5 km, which is equivalent to 64 (8x8) picture elements (pixels) per 3DNEPH grid point. The SGDB is continuously updated with new satellite imagery. The entire infrared SGDB is updated approximately every 6 to 12 hours, while the entire visual SGDB is updated every 18 to 24 hours.

2.1 Satellite Processor

A threshold technique is used to process the satellite imagery to obtain the cloud information. This technique consists of comparing the satellite pixel information with the appropriate background information. The infrared satellite imagery is compared with a surface temperature field, while the visual imagery is compared with a background brightness field.

The processing of the infrared satellite imagery is accomplished by building a histogram using the 64 grayshades associated with a 3DNEPH grid point (Fig. 2). Pixels with similar temperature characteristics are grouped into "modes" using the following criteria:

(a) A single grayshade that contains 6 or more samples.

(b) A group of adjacent grayshades containing 12 or more samples.

The lowest temperature associated with each mode is selected as the representative temperature of the mode. If this temperature is lower than the threshold temperature associated with the grid point, the pixels associated with the mode are classified as cloud. The threshold temperature is determined using the surface temperature associated with the

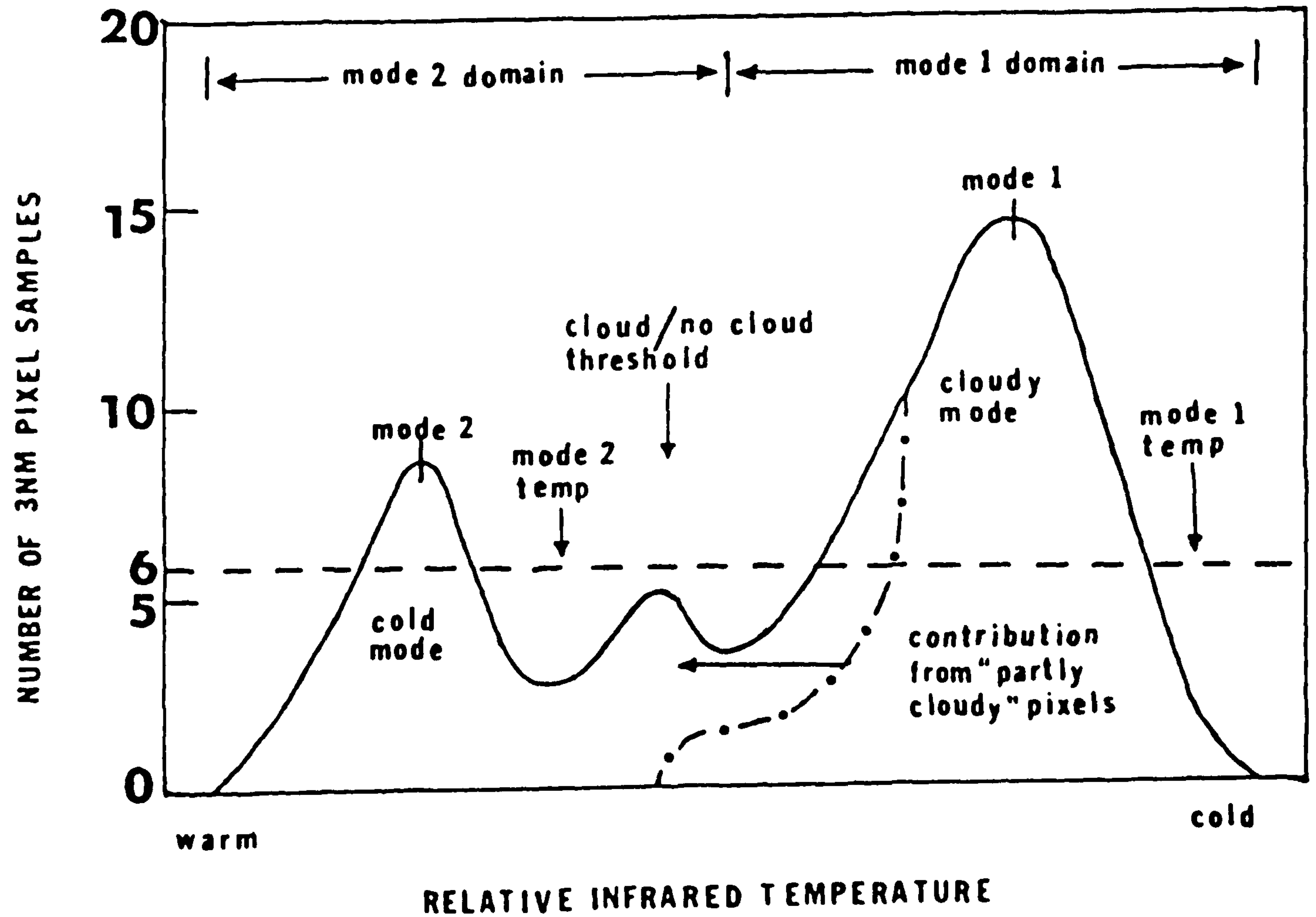

Fig. 2 Schematic of an infrared frequency distribution for a single grid point.

grid point and an empirically derived adjustment factor, which is a function of the variability of the background brightness associated with the grid point (Fig. 3). Each cloud mode represents a distinct cloud layer and the temperature associated with the mode is used to determine the height of the top of the cloud layer. A certain percentage of the pixels that lie outside the mode are included in the mode to compensate for the pixels that represent partly cloudy conditions. When it is not possible to determine a mode, a cloud/no cloud decision is made for each pixel by comparing the pixel temperature with the threshold temperature (Fig. 2).

In processing the infrared imagery, corrections are made for limb-darkening, water vapor attenuation, pixels that represent partly cloudy scenes, and variations in the reliability of the surface temperature analysis. Limb-darkening is due to the increase in the depletion of the infrared radiation as the satellite scan moves away from the subtrack, resulting in an increase in the atmospheric path length. In addition, an automated bias correction is applied to the infrared cloud analysis to correct for other systematic anomalies. A detailed description of all the corrections can be found in an AFGWC Technical Memorandum (Fye, 1978). The appropriate surface temperature analysis and temperature profiles are used to determine the cloud amounts and cloud top heights, respectively. The height determination is based on the assumption that the radiation is emitted by a blackbody. Therefore, emitters that do not act as blackbodies, for example, thin cirrus, may result in erroneous cloud top heights. The surface temperature analysis and temperature profiles are generated from conventional information and other AFGWC data

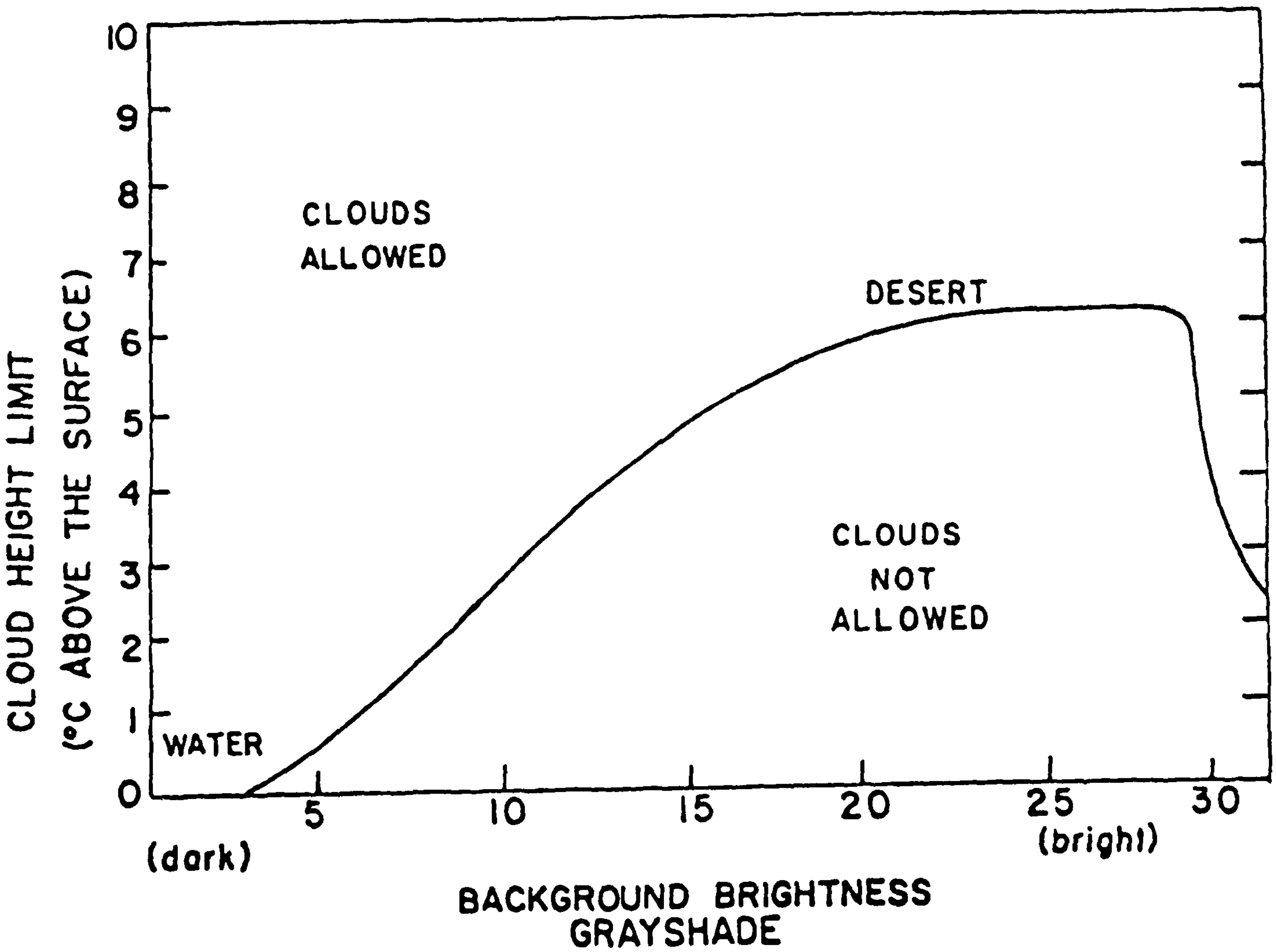

Fig. 3 Infrared cloud cut-off curve used to limit low clouds over bright areas.

bases.

The cloud amount from the visual satellite processor is obtained by comparing the 64 pixels associated with a 3DNEPH grid point with the appropriate background brightness value assigned to that grid point. A dynamic 44 km resolution background brightness field is maintained for each satellite. This field is updated whenever new visual satellite imagery is available. Because the albedo can exhibit considerable variability over the 44 km grid, the cloud/no cloud threshold is a function of both the average background brightness and the variability of the 64 5-km pixels associated with a 3DNEPH grid point. The variability of the pixel brightnesses associated with a 3DNEPH grid point, as a function of the average background brightness, is depicted in Fig. 4. Visual satellite imagery that is located in areas of sunglint, the morning terminator, or snow fields is not used in processing the visual data.

In addition to determining cloud amounts and cloud top information, a cloud type is also determined from the satellite imagery. The cloud type at a 3DNEPH grid point is determined by comparing the average infrared and visual brightness associated with the grid point and the variability of the infrared and visual brightnesses of the 64 5-km pixels (Fig. 5).

2.2 3DNEPH Data Product

The satellite, conventional, and continuity fields are integrated to produce the final 3DNEPH cloud analysis. First, the visual and infrared satellite analyses are combined to produce a single satellite cloud

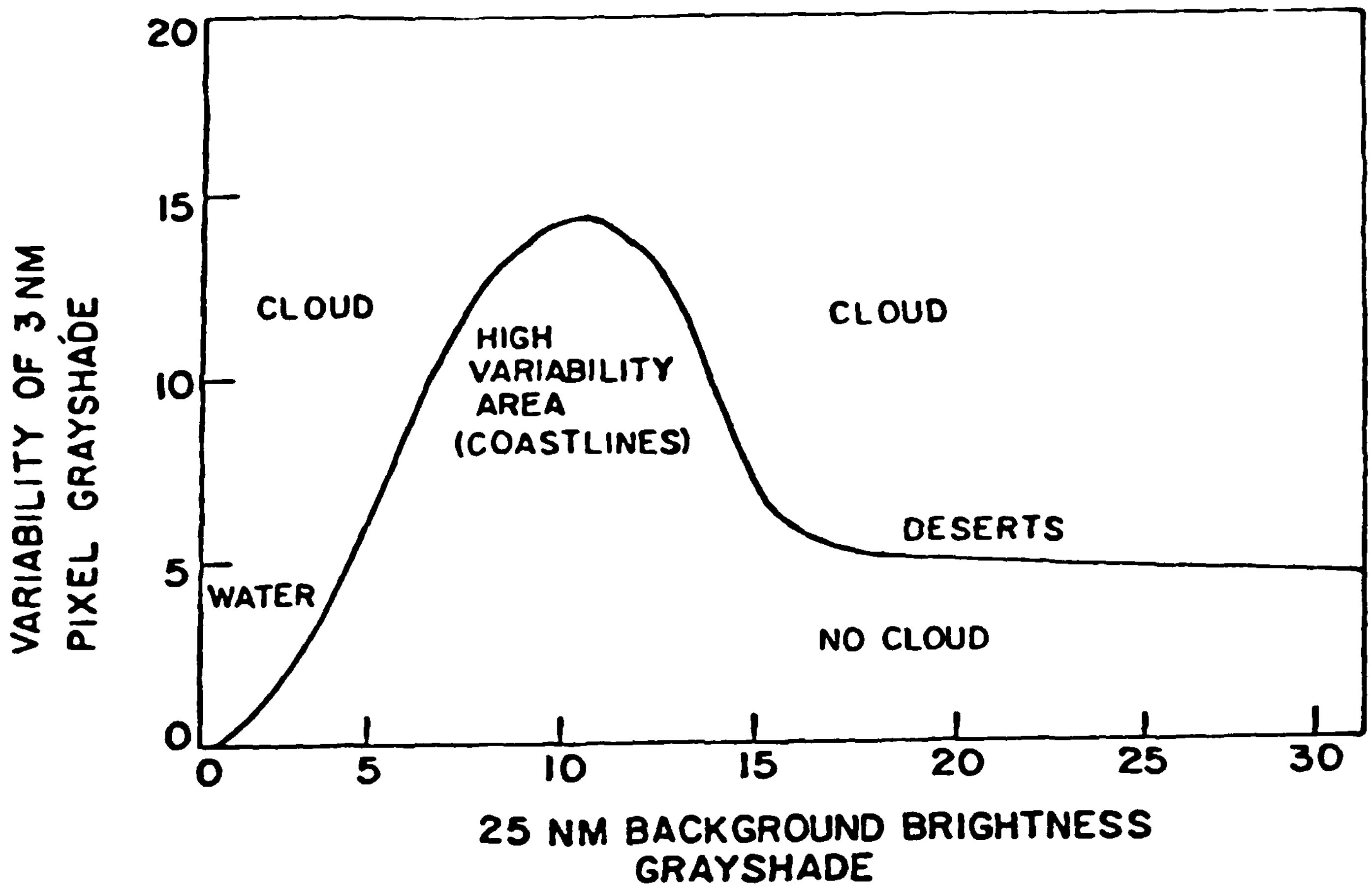

Fig. 4 Generalized variability curve of 5 km pixel grayshade as a function of 44 km background brightness grayshades. This curve is the basis of the cloud/no-cloud decisions made in the visual data processor. The high amplitude area corresponds to coastal and other high variability terrain features. Approximately 95 percent of all 44 km grid points are found in the background brightness range of 1 to 6.

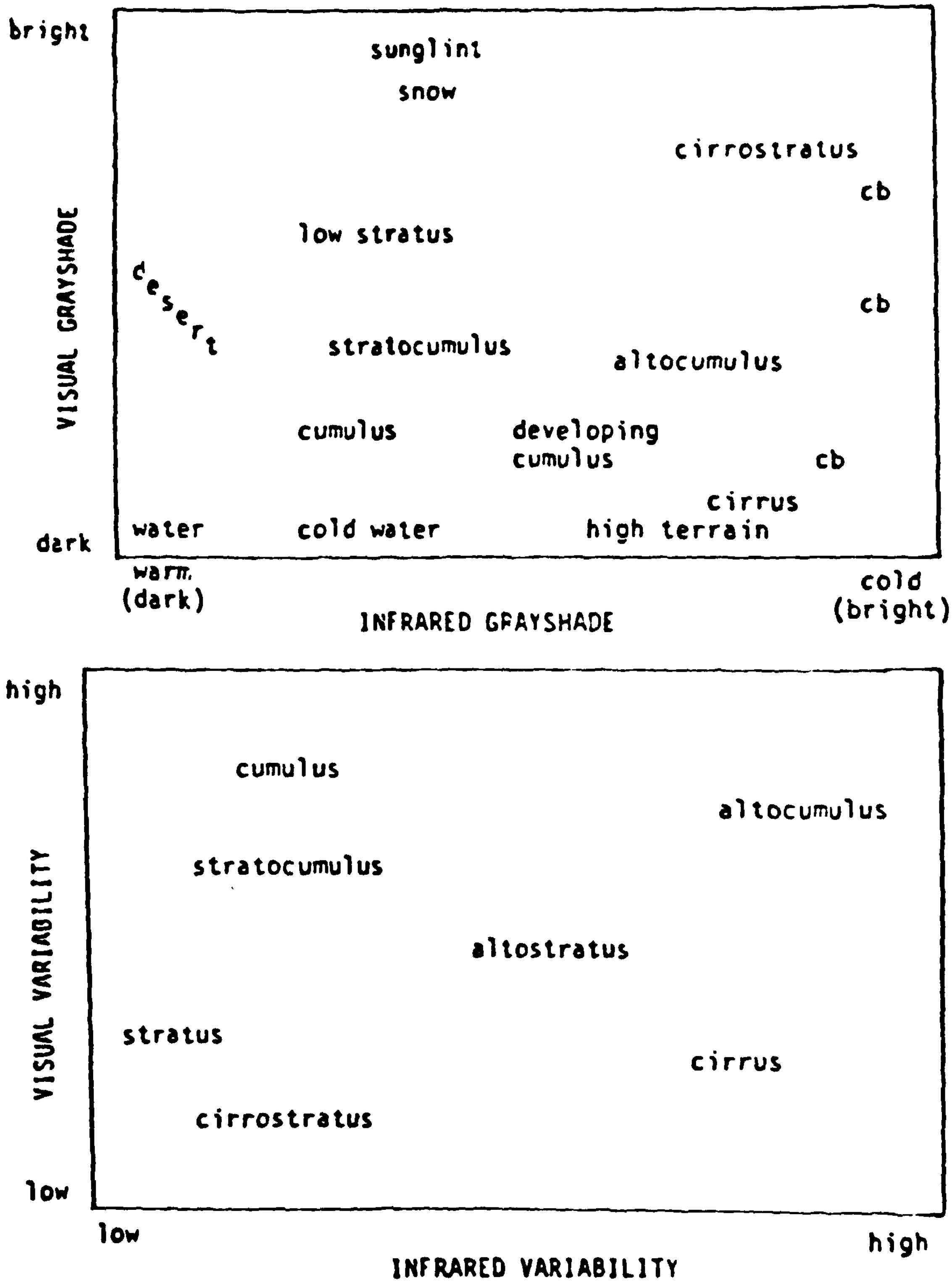

Fig. 5 Graphical display of the relationship between infrared and visual variability for the typing of clouds.

analysis. In determining the satellite total cloud cover from the visual and infrared satellite analysis, the analysis representing the greatest cloud amount is used, assuming both have the same valid time. This decision is based on the fact that the visual cloud analysis tends to underestimate the amount of high thin clouds, while the infrared analysis has a tendency to underestimate the amount of low clouds.

The satellite analysis is then integrated with the conventional analysis to produce the final 3DNEPH cloud analysis. For 3DNEPH grid points that are not updated by the satellite or conventional cloud analysis, the continuity (previous 3DNEPH cloud analysis) cloud fields are used.

After a series of automated consistency checks, the final 3DNEPH cloud analysis is quality controlled by the duty forecaster. The forecaster has the capability of modifying the 3DNEPH data base by using an interactive graphic system.

The final 3DNEPH cloud analysis consists of the following information for every 3DNEPH grid point: total cloud coverage, minimum cloud base, maximum cloud top, present weather, low, middle, and high cloud types, and the 15 layered cloud amounts to the nearest 5%.

3. 3DNEPH CLOUD CLIMATOLOGY

One of the major problems encountered with the 3DNEPH data base is the tremendous volume of data that must be processed to produce a cloud climatology. It is for this reason that certain adjustments to the data were made during processing. These steps will be described in detail in the sections below. A brief outline of the procedures used to produce the cloud climatology follows.

- A compaction scheme was used to convert from a 15 layer data base to a 3 layer data base.
- The high resolution (44 km) 3DNEPH horizontal grid points were mapped to the coarser Nimbus 7 Earth Radiation Budget Sub-Target Area (ERB/STA) grid system (160 km).
- The valid times (Greenwich) of the 3DNEPH were converted to local times.

Cloud climatologies for the Northern Hemisphere were compiled for two months of the first FGGE year (January and July 1979).

3.1 3DNEPH LMH Data Set

Most cloud climatologies produced in the past have confined the vertical resolution of the cloud field to 3 layers, LMH (low, middle, and high). The 3DNEPH differs from other cloud data bases in the number of layers of cloud data stored (15) and the variable layer heights that are employed. Of the 15 layers of cloud data, the lowest 6 are AGL (above ground level) and the upper 9 are MSL (mean sea level). Each layer has an associated base, top, and cloud amount. In this study the 15 3DNEPH layers were compacted into 3 LMH layers using the following scheme:

(1) In order to compact the 15 3DNEPH layers to obtain low, middle, and high cloud amounts, it is necessary to define low/middle and middle/high cloud boundaries. The low/middle cloud boundary was defined as the surface height plus 2 km, while the middle/high cloud boundary was set at the height of the -20°C isotherm (Fig. 6). When 3DNEPH layers containing nonzero cloud amounts were at or near a boundary, the 3DNEPH cloud type was used to help determine in which LMH layer to place the 3DNEPH layer.

(2) One cloud amount for each LMH layer was obtained by combining the 3DNEPH cloud layer amounts inside the LMH layer using either a maximum overlap technique (for contiguous 3DNEPH layers) or an adjustable random overlap technique (for non-contiguous layers). In the latter technique, an adjustable random factor was computed to specify the degree of random overlap used when 2 noncontiguous 3DNEPH cloud layers were combined. This factor was dependent on the spacing between the two layers and the height of the lowest layer, and took on values from 0 (maximum overlap case) to 1 (complete random overlap case). This scheme was patterned after the one contained in the AFGWC 3DNEPH analysis algorithm, which computes the total cloud amount by a statistical summation of the 15 layers of 3DNEPH cloud data. For this reason, no adjustments were made to the original 3DNEPH total cloud amount.

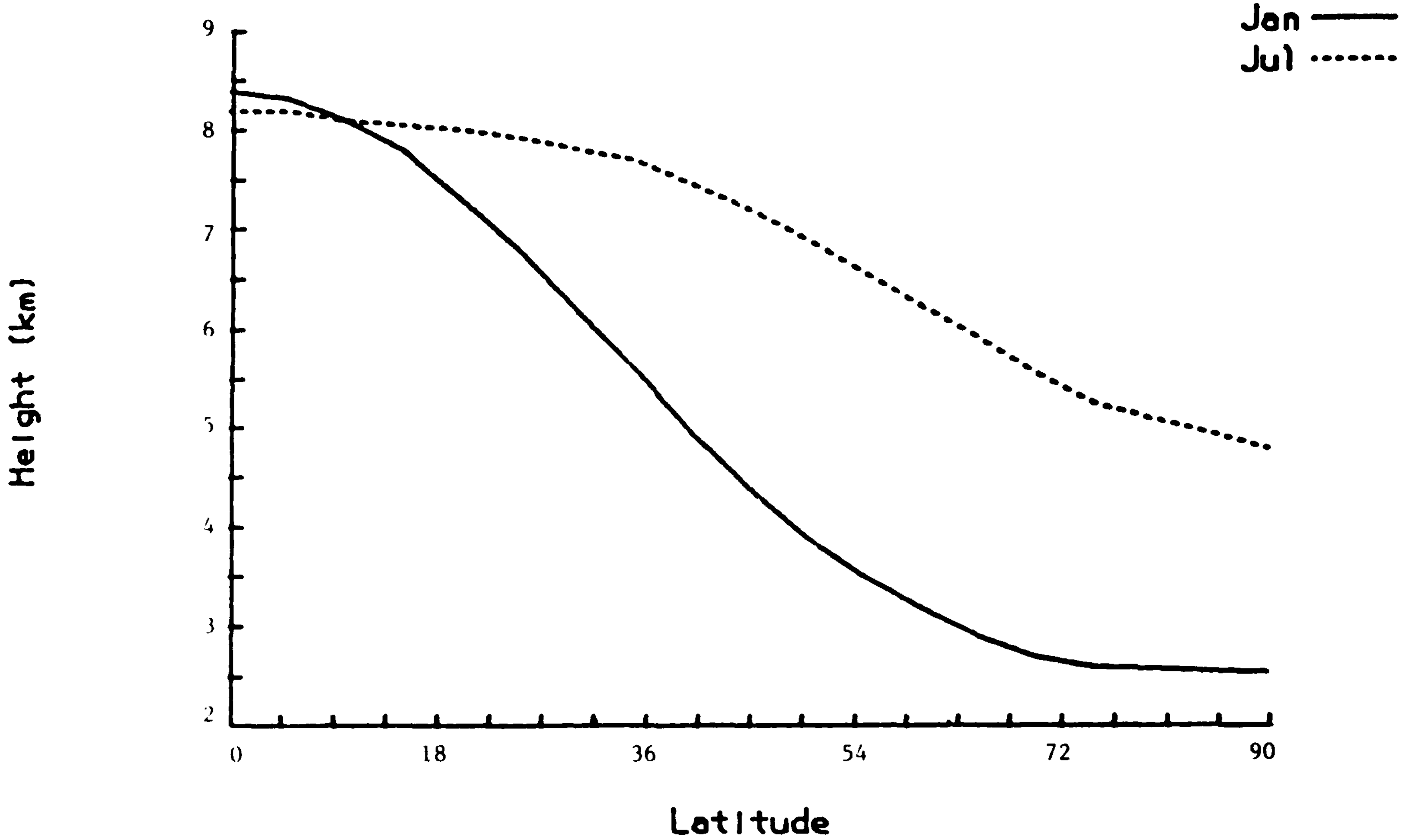

Fig. 6 Middle/high cloud boundary as a function of latitude for January and July based on the -20°C isotherm.

3.2 Nimbus 7 ERB Grid

For most research on a hemispheric or global scale, a horizontal cloud field resolution of 100 km (~1° of longitude) would be sufficient. The horizontal separation of the 3DNEPH grid points is approximately 44 km, which represents a much finer resolution than would normally be required for the studies we were undertaking. Compiling a cloud climatology at this grid resolution would require a significant increase in the computation time over that for a data set of coarser resolution. Since most cloud/radiation models are based on a latitude-longitude type grid, it was decided to map the 3DNEPH grid points and their associated vertical cloud data to the Nimbus 7 ERB (Earth Radiation Budget) grid. This grid system was chosen to facilitate future comparisons of the 3DNEPH data base with other cloud data bases, as well as the ERB product. The ERB grid divides the surface of the earth into 2070 (1035 per hemisphere) equal area TAs (target areas) (see Fig. 1). Each TA has a resolution of approximately 500 km and is subdivided into 9 (3x3) STAs (sub-target areas). All 3DNEPH grid points lying inside a specific STA were averaged. Up to 45 3DNEPH grid points could be mapped into a single STA near the equator, while at the poles the number was normally less than 15. The effect of this mapping was to reduce the size of the cloud field and smooth out the contributions of individual 3DNEPH grid points.

3.3 Local Time Conversion

The valid times for the 3DNEPH are 00Z, 03Z, ..., 21Z. For future research to be undertaken at the University of Utah using the 3DNEPH cloud data base, it was necessary to convert these times to local times.

This was accomplished by dividing the Northern Hemisphere into 8 sections bounded by meridians corresponding to 3-hour time intervals from the prime meridian (i.e., 45°, 90°, 135°, 180°, 225°, 270°, and 315°). For a given 3DNEPH GMT time, each section represents a different local time depending on the longitudinal distance from the prime meridian. To obtain the local time from GMT, time must be added to the GMT at longitudes east of the prime meridian and subtracted from the GMT at longitudes west of the prime meridian.

3.4 January and July Cloud Climatology

The total cloud climatology (Fig. 7) reflects the major circulation features. The maximum total cloud amount in the vicinity of the equator correlates with the position of the intertropical convergence zone (ITCZ). The minimum total cloud amount north of this area is associated with the subtropical high. The maximum, extending from approximately 36°N to 60°N is associated with the midlatitude storm tracks. The maximum north of 72°N is most likely due to an error in the processing of the IR satellite information (visual satellite information does not exist for the polar latitudes in the wintertime hemisphere). If the IR satellite greyshades are incorrectly converted to a temperature and/or the surface/atmospheric temperature information is incorrect, then it is possible that the land surfaces in the polar regions are being interpreted as clouds. The January 1977 zonal cloud climatology developed by Gordon et al. (1984) based on the 3DNEPH cloud information also has extremely high total cloud amounts north of approximately 75°N.

Equatorward of 50°N, the total cloud amount reflects the variations of the low and middle cloud amounts. In this region, the low cloud

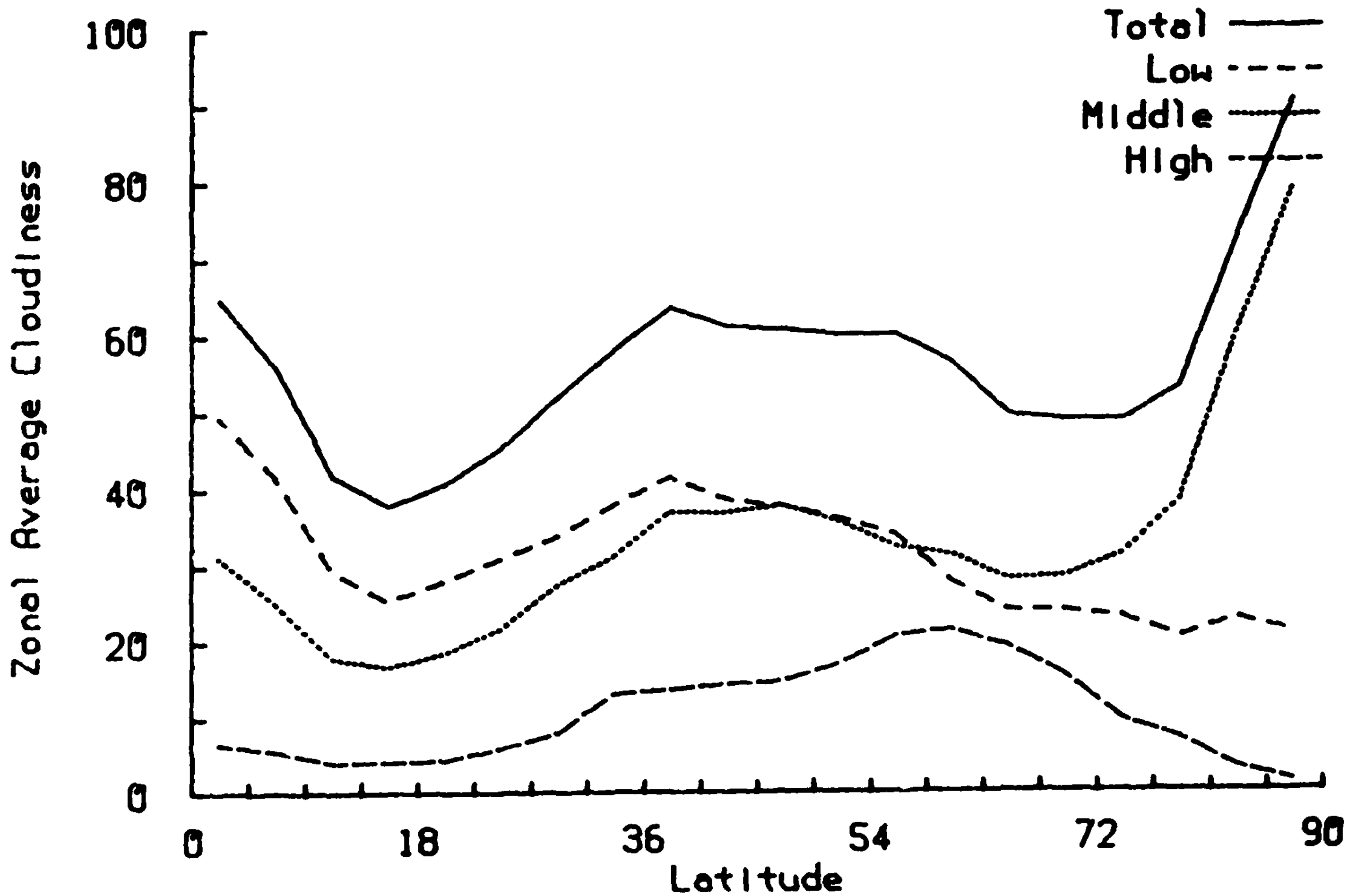

Fig. 7 Northern Hemisphere low, middle, high, and total zonal cloud climatology for January 1979.

amount is greater than the middle cloud amount. North of 72°N, the analysis is not reliable, but between 50°N and 72°N, the middle cloud amount exceeds the low cloud amount. The trend of the high cloud amount is similar to the total cloud amount north of 25°N. Equatorward of approximately 10°N, both the low and middle cloud amounts increase, while the high cloud amount remains fairly constant. Compared to the climatology of London (1957) and Barton (1983), the zonal 3DNEPH high cloud amounts are 10-15% less.

The January tropical cloud maximum, associated with the ITCZ, moves approximately 10° northward in July and is better defined (Fig. 8). In addition, the amplitude of the maximum increases significantly. The magnitude of this maximum appears to be unrealistic, but its presence is well documented by other cloud climatologies. In late June 1979, the satellite data from a new DMSP satellite were used operationally in the 3DNEPH analysis. Unfortunately, it takes two or three months to gather sufficient statistics to tune the visual and IR processor. The relatively low cloud amounts south and north of this maximum are associated with the tropical and subtropical high pressure cells. In July, the midlatitude storm tracks move northward and are better defined. The shift in the position of the storm tracks is from approximately 35°N to 50°N. Unlike the January zonal cloud analysis, the July analysis north of 75°N is useable.

3.5 Comparison with Other Cloud Climatologies

Hughes (1984) graphically presented the zonal averaged total cloud amounts for a number of climatologies. This information has been tabulated for five of the climatologies and is presented in Table 2.

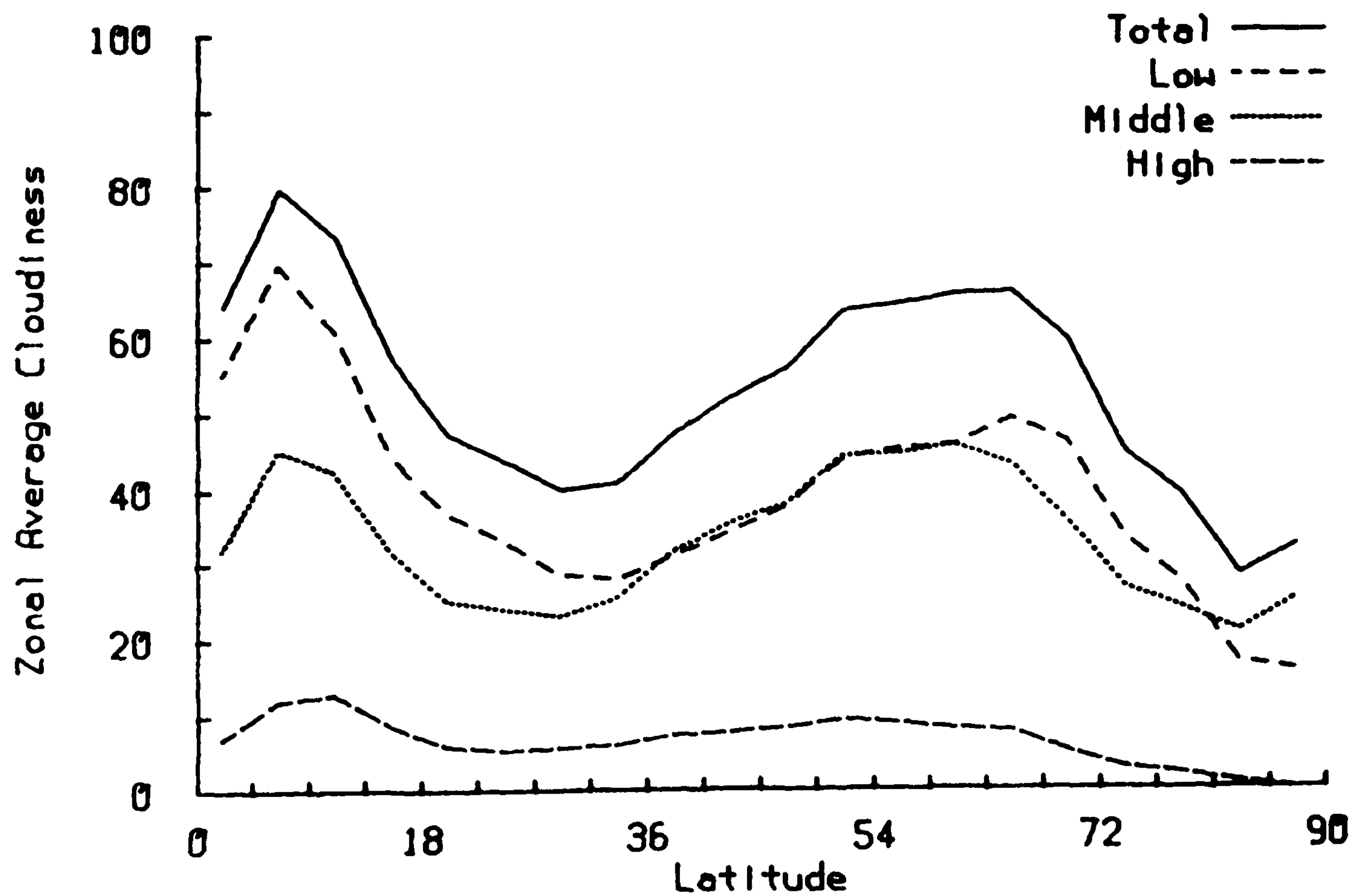

Fig. 8 Northern Hemisphere low, middle, high, and total zonal cloud climatology for July 1979.

Table 2. The 3DNEPH zonal total cloud climatology and five selected total cloud climatolgies (after Hughes, 1984).

	Brooks (1927)	London (1957)	Schutz & Gates (1971) ETAC (1971)	Schutz & Gates (1971) Miller & Feddes (1971)	Berlyand & Strokina (1980)	Range	Average	3DNEPH
Jan.								
90-80	38	40	48	--	54	16	45	79
80-70	56	47	49	--	59	12	53	50
70-60	57	58	58	--	65	8	60	51
60-50	59	63	66	49	69	20	61	59
50-40	58	59	65	63	65	7	62	61
40-30	50	51	58	50	59	9	54	59
30-20	42	39	45	34	52	18	42	46
20-10	40	36	--	18	48	30	35	40
10-0	48	47	--	32	57	25	46	59
July								
90-80	86	64	83	94	84	30	82	31
80-70	75	69	78	81	79	12	76	46
70-60	68	66	69	56	72	16	66	64
60-50	63	63	73	57	73	16	66	64
50-40	51	55	62	50	61	12	56	54
40-30	42	41	51	36	51	15	44	43
30-20	45	42	49	38	51	13	45	44
20-10	59	49	--	40	62	22	52	61
10-0	56	54	--	44	64	20	54	72

The results of the 3DNEPH zonal climatologies for Janaury and July are also listed in this table. All January cloud climatologies listed show enhanced total cloud amounts associated with the ITCZ (0-10°N) and the midlatitude storm tracks (20-70°N). In addition, all cloud climatologies depict the region associated with the subtropical high (10-20°N) as a region of relatively low total cloud amounts. The greatest difference between the 3DNEPH climatology and the average of the other climatologies (referred to as the average climatology) occur for the 80-90°N zonal belt. As mentioned earlier, the 3DNEPH analysis is not reliable for the polar regions of the wintertime hemisphere. The difference between the average climatology and the 3DNEPH climatology is less than half of the range given for the five climatologies for all latitude belts except the latitudes from 60-70°N and 80-90°N. The average of the absolute difference between the average climatology and the 3DNEPH climatology is 8.4%.

The 3DNEPH July climatology differs considerably from the average climatology for the most southern latitude belt and the two most northern latitude belts. These latitude belts also exhibit considerable range between the five climatologies. As noted earlier, the July cloud amounts in the tropics may be overestimated by the IR processor due to insufficient tuning factor statistics. The absolute difference between the 3DNEPH and average climatology for July is 12.3%.

Henderson-Sellers (1986) has compiled a layered cloud climatology from a compressed version of the 3DNEPH data archive for the same two months in 1979 as those used in this study. A comparison of the Northern Hemisphere monthly mean low, middle, high, and total cloud amounts derived in the two studies is shown in Table 3. The results are in good agreement, especially for January. For July, the major differences are in the high cloud layered amounts with Henderson-Sellers reporting significantly more high cloud coverage than the present study. The reason for this is in the definition of the middle/high cloud boundary. Henderson-Sellers uses a value of 6 km AGL, which remains constant with latitude, while the height of the -20°C isotherm is used as the middle/high cloud boundary (see Fig. 6) in this study. From this figure, it is observed that in July the height of this temperature level is greater than 6 km from the equator up to 60°N latitude. Therefore, some cloud layers above 6 km that would be labeled high clouds by Henderson-Sellers may still be considered to lie in the middle cloud region, especially at latitudes less than 30°N, using the temperature-based middle/high cloud boundary. For the zonally averaged case, comparisons of layered and total cloud amounts show good agreement over the entire Northern Hemisphere for both months.

Table 3. Northern Hemisphere layer and total cloud amounts for January and July 1979 compared with Henderson-Sellers (H-S, 1986).

	January		July	
	Present	H-S	Present	H-S
Low	34.0	33	42.7	44
Middle	28.4	27	34.0	32
High	10.3	10	7.8	13
Total	53.3	51	56.3	58

3.6 Cloud Field Graphs

Cloud climatologies for the Northern Hemisphere were compiled for January and July 1979 using the AFGWC (Air Force Global Weather Central) archived 3DNEPH (three-dimensional Nephanalysis) data base. Cloud fields were derived at 8 local times for each day of the month and for each of the 4 cloud types (low, middle, high, and total). Monthly mean cloud fields for these analysis time periods (00L, 03L, ... 21L) were also produced, as well as an overall monthly mean cloud climatology. To present each of the above mentioned cloud fields would require more than 1000 individual graphs for each month. Therefore, only selected monthly mean cloud fields will be shown. Graphs of the daily diurnal cloud fields (00L and 12L) for each cloud type are available on microfiche and a complete version of the cloud data base is available on magnetic tape or can be accessed on the mass storage system at NCAR (National Center for Atmospheric Research).

The plots of the 3DNEPH cloud fields that follow are divided into 2 groups, one for each of the two months in which data was available (January and July 1979).

(1) Monthly Mean cloud climatology for each of the LMHT cloud types (Figs. 9-12 and 21-24)

(2) Monthly mean cloud climatologies for the 00L and 12L time periods and for each cloud type (Figs. 13-20 and 25-32).

Contour intervals of 20% cloud amount were used in the graphs of monthly mean low, middle, and total cloud climatologies, while 10% was used for the monthly mean high cloud climatologies.

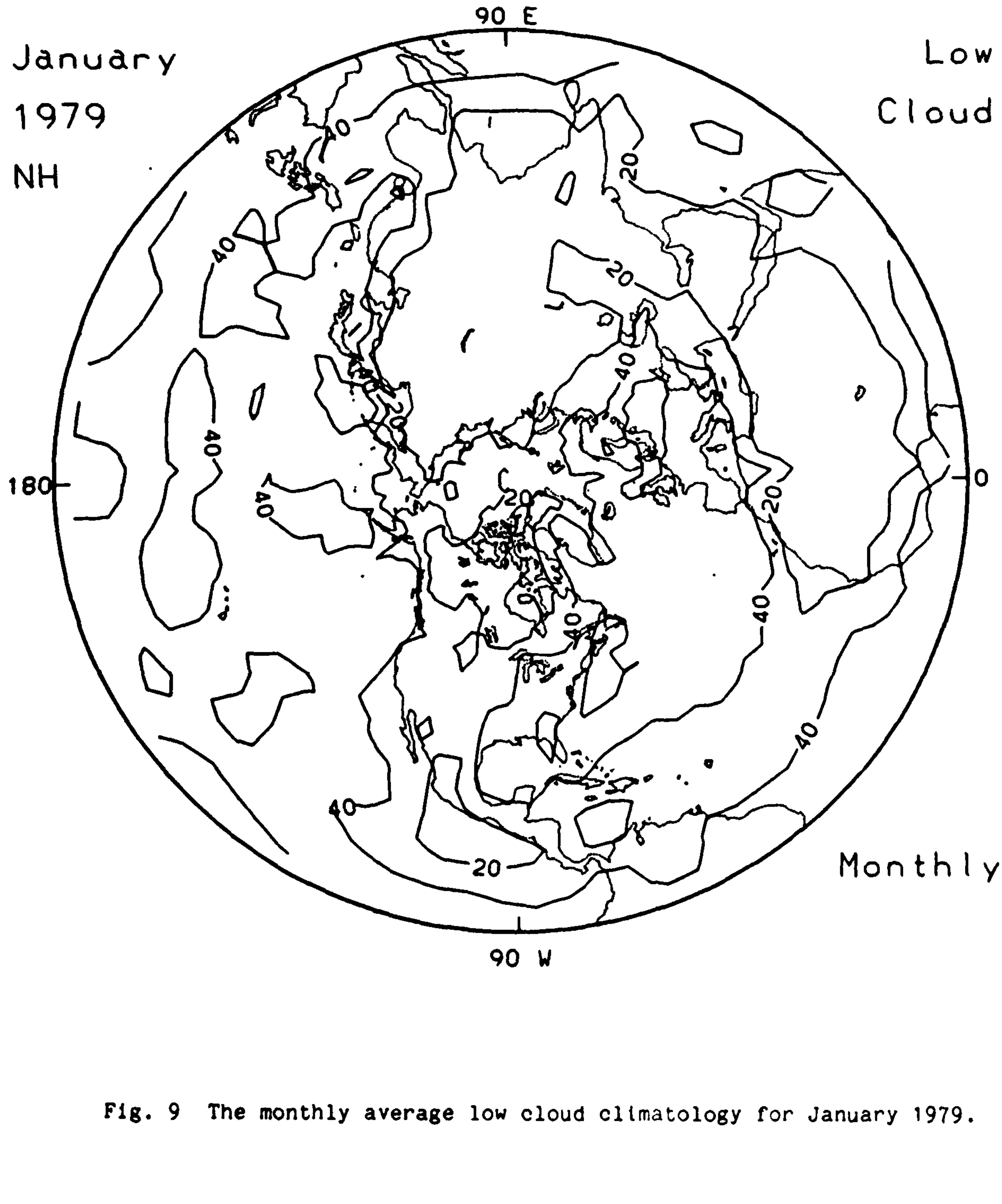

Fig. 9 The monthly average low cloud climatology for January 1979.

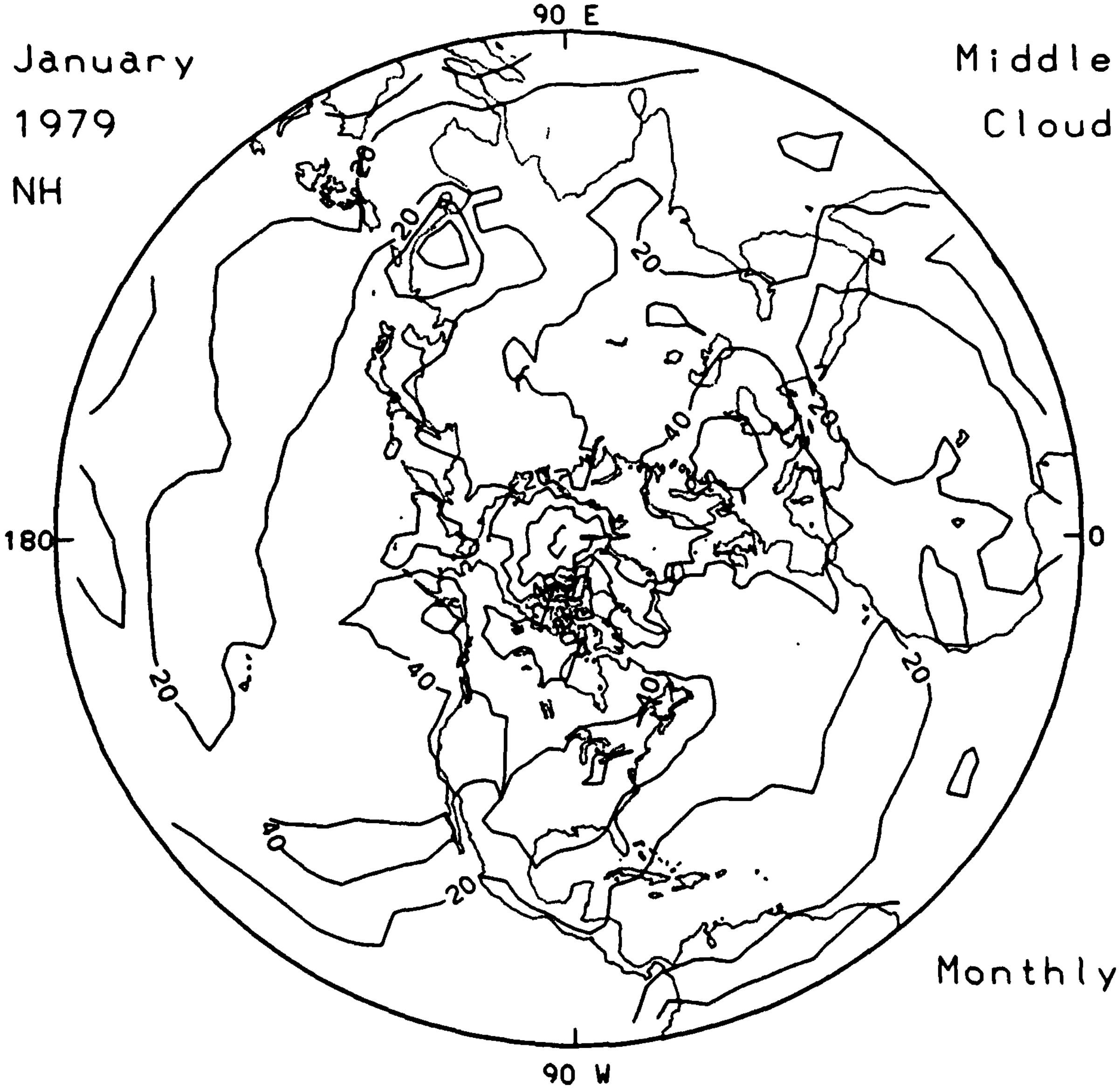

Fig. 10 The monthly average middle cloud climatology for January 1979.

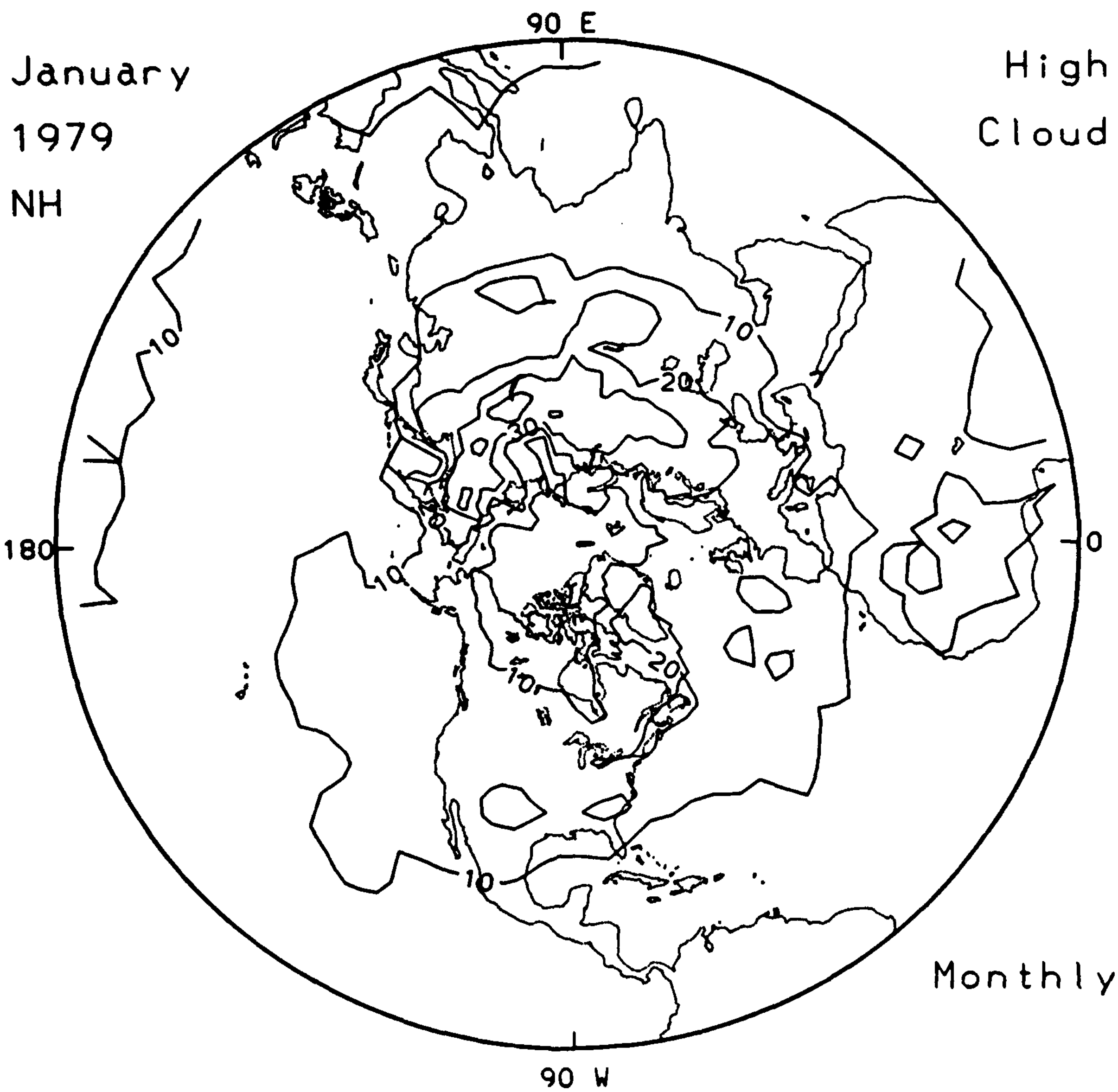

Fig. 11 The monthly average high cloud climatology for January 1979.

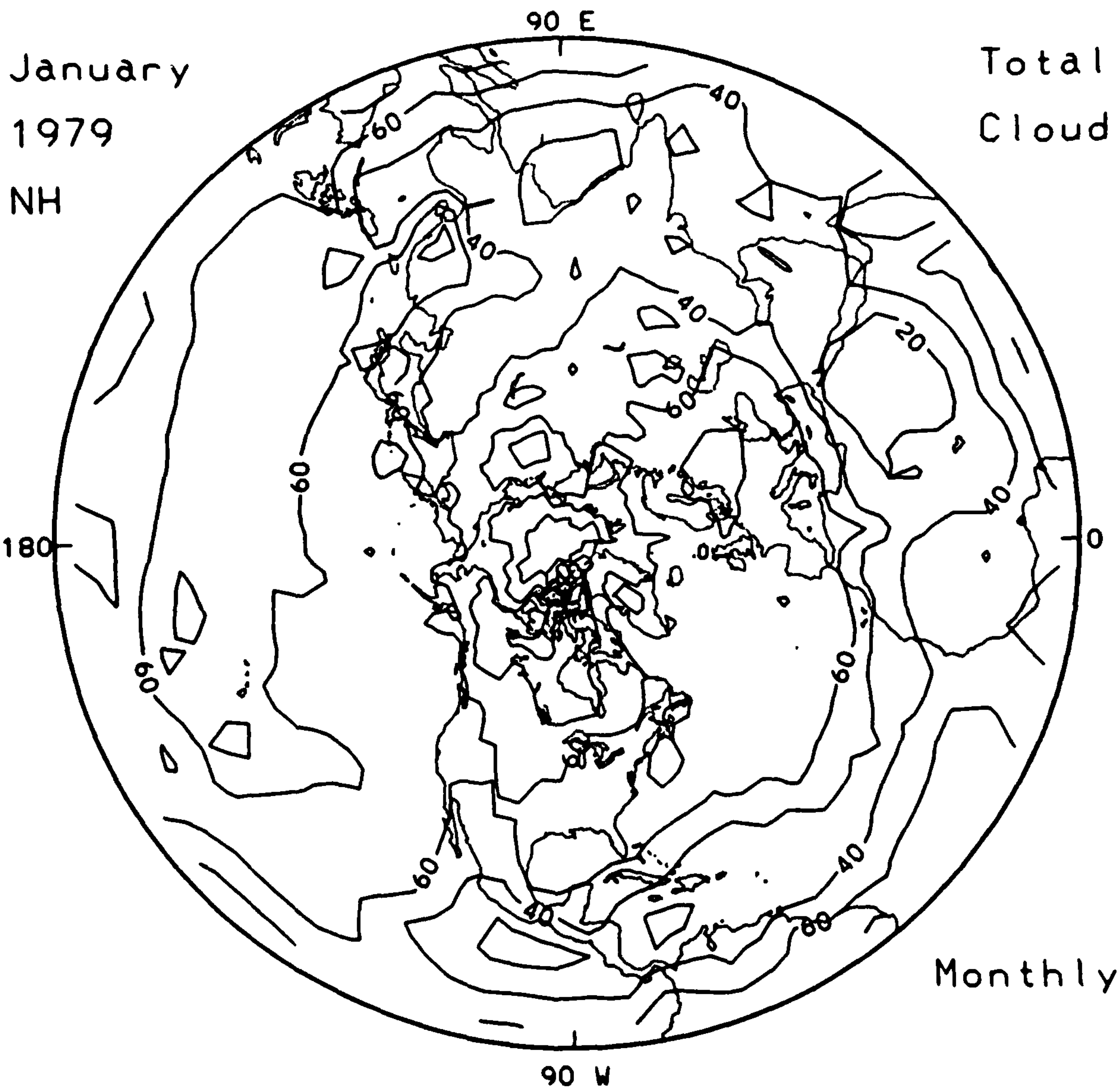

Fig. 12 The monthly average total cloud climatology for January 1979.

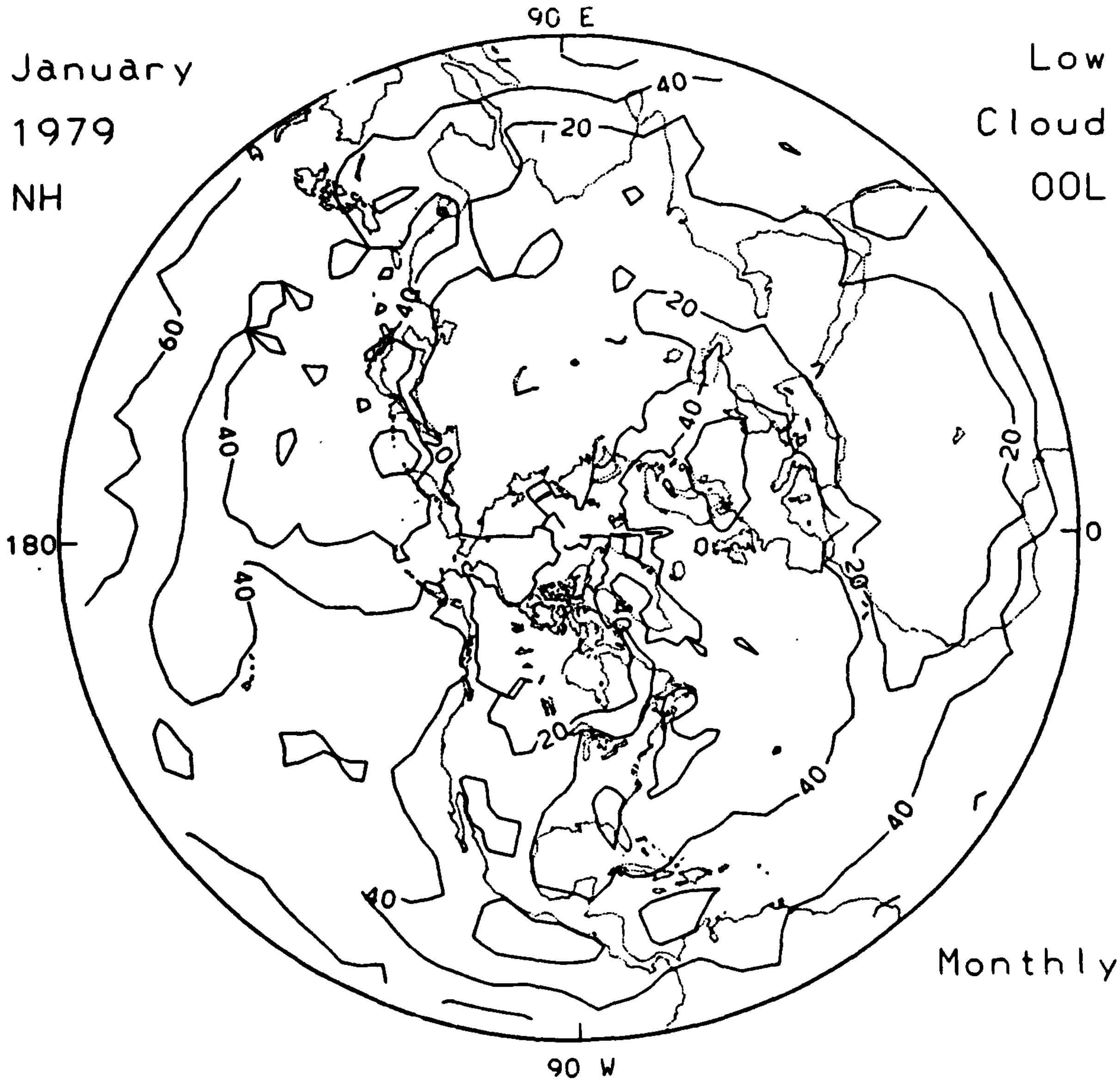

Fig. 13 The monthly average low cloud climatology for January 1979 at 00L.

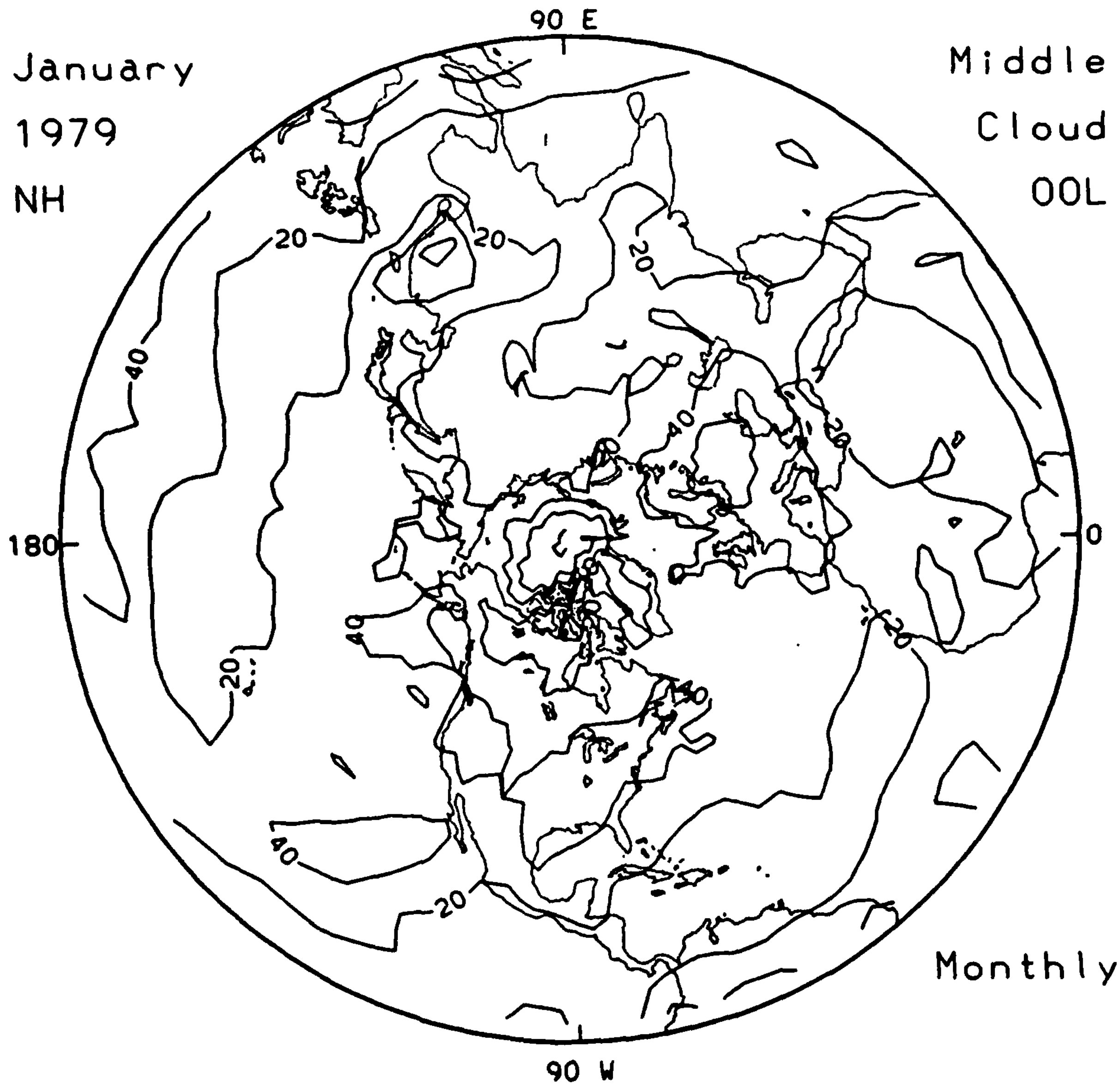

Fig. 14 The monthly average middle cloud climatology for January 1979 at 00L.

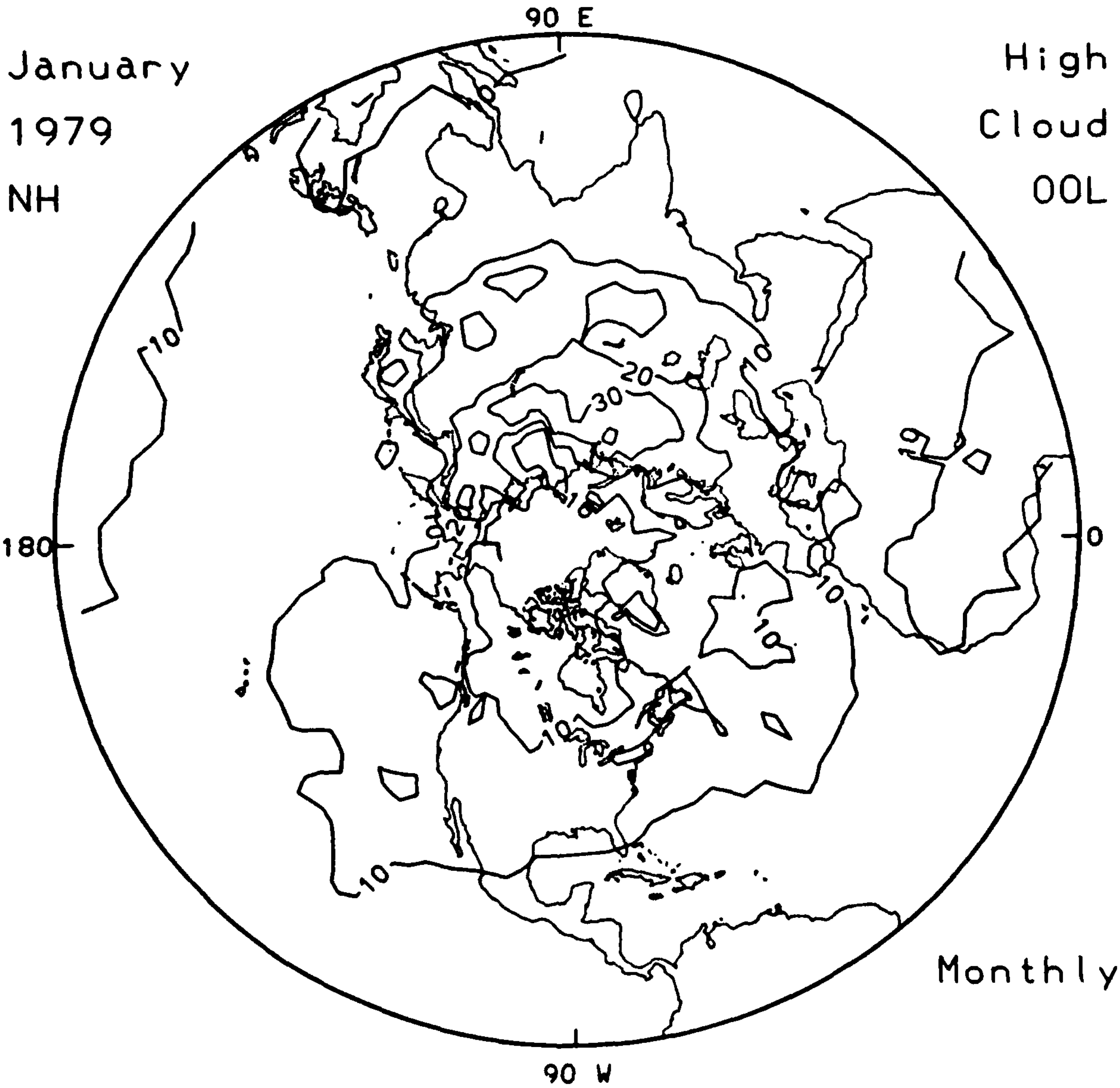

Fig. 15 The monthly average high cloud climatology for January 1979 at 00L.

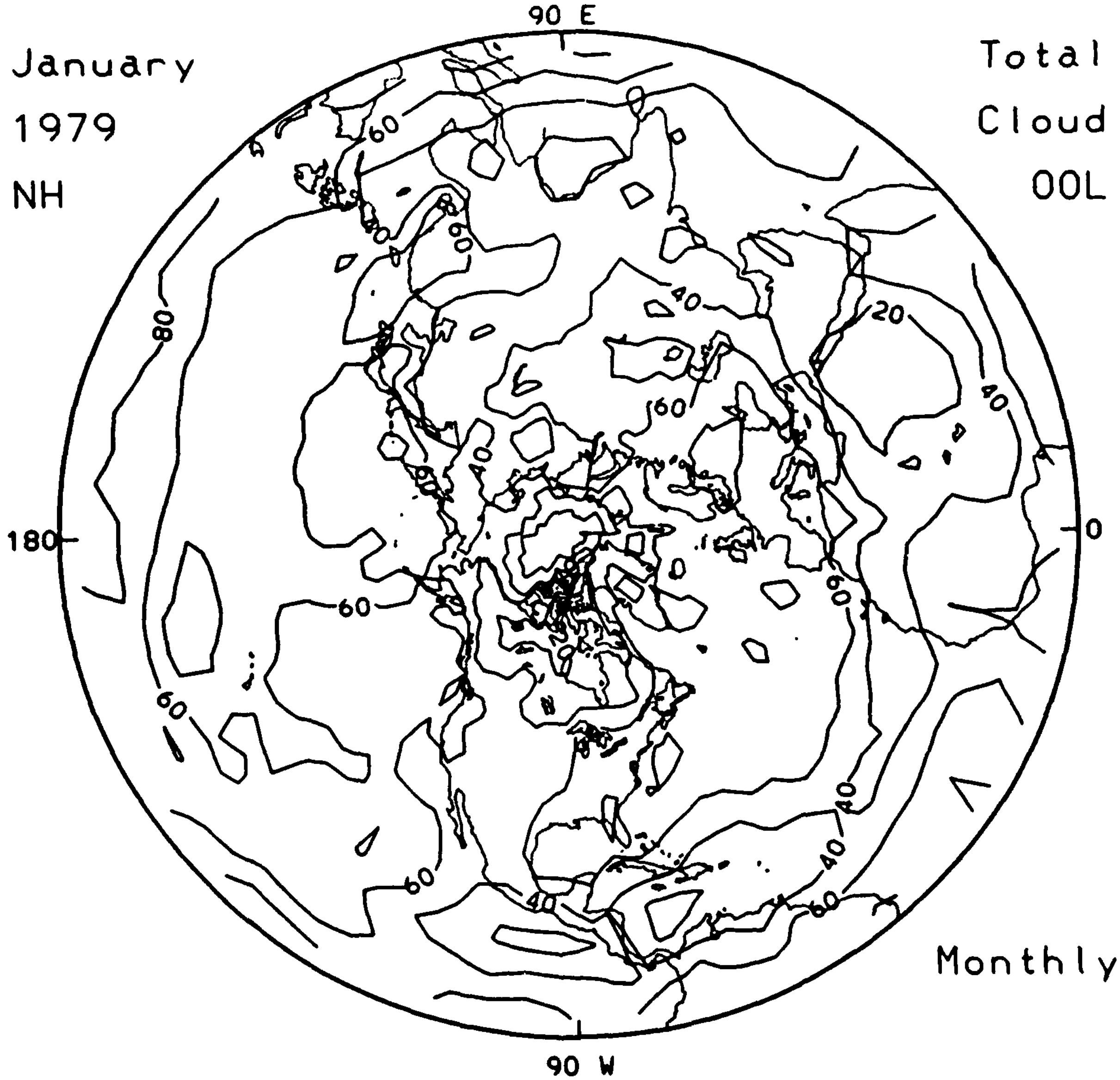

Fig. 16 The monthly average total cloud climatology for January 1979 at 00L.

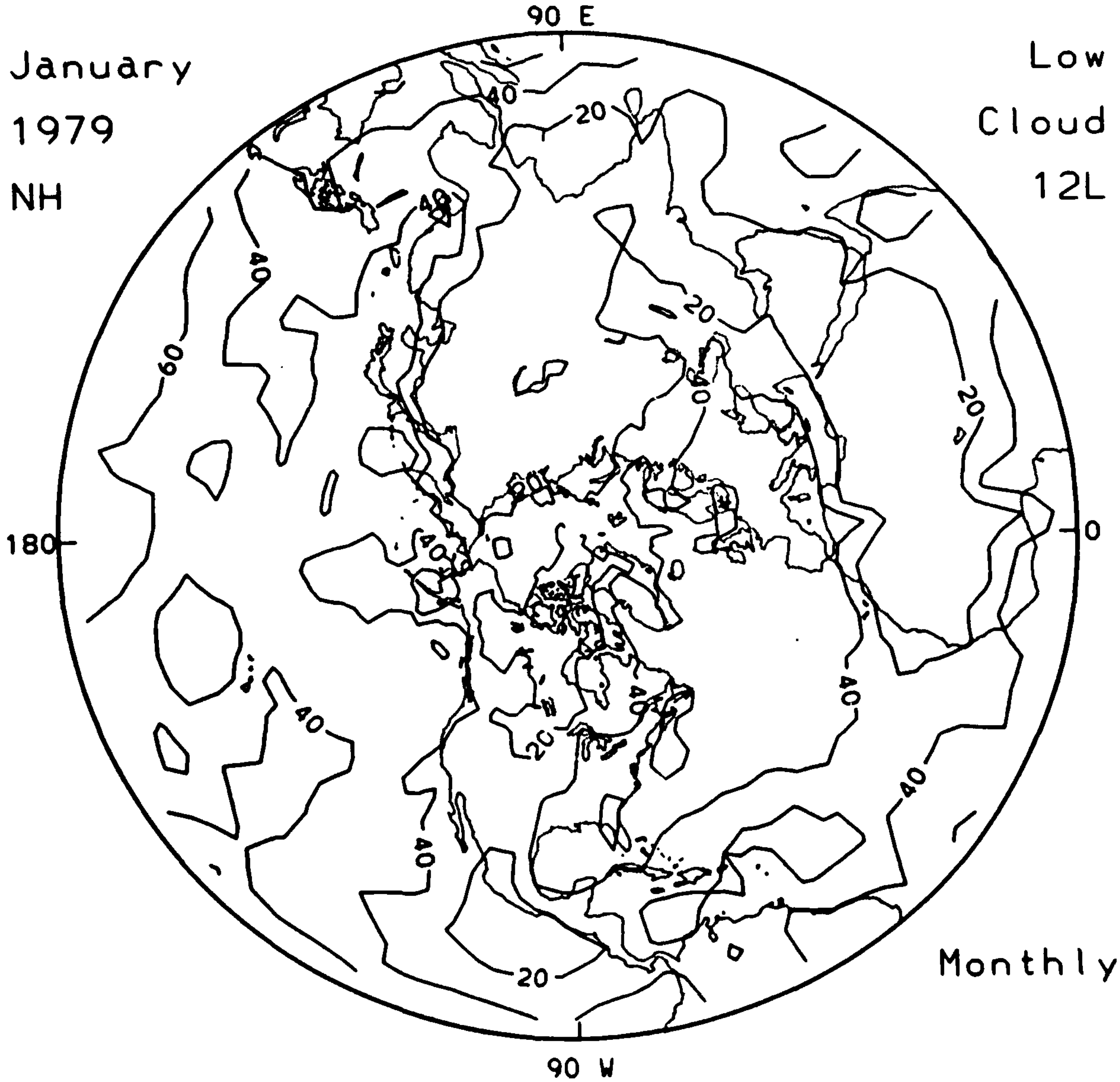

Fig. 17 The monthly average low cloud climatology for January 1979 at 12L.

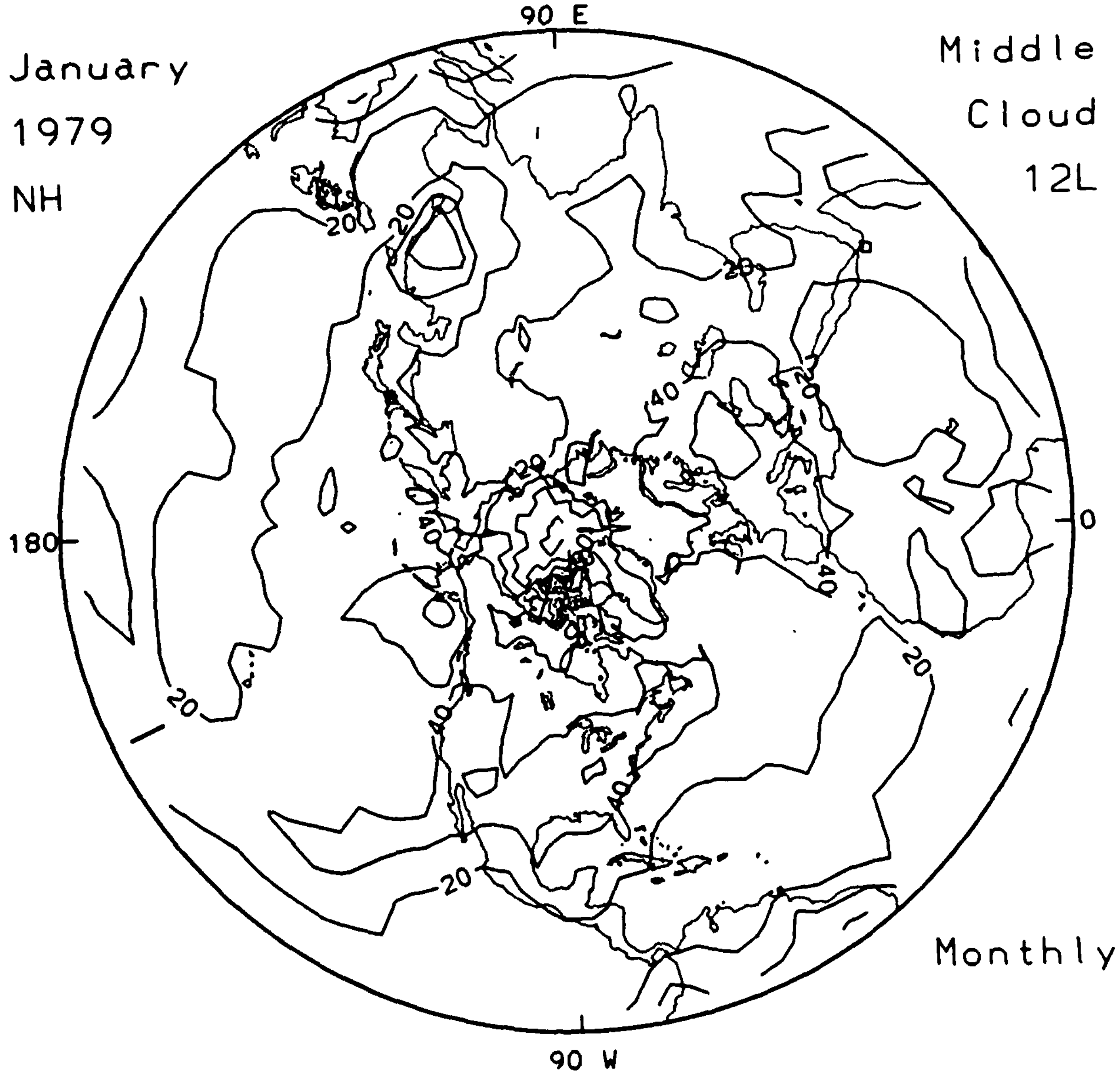

Fig. 18 The monthly average middle cloud climatology for January 1979 at 12L.

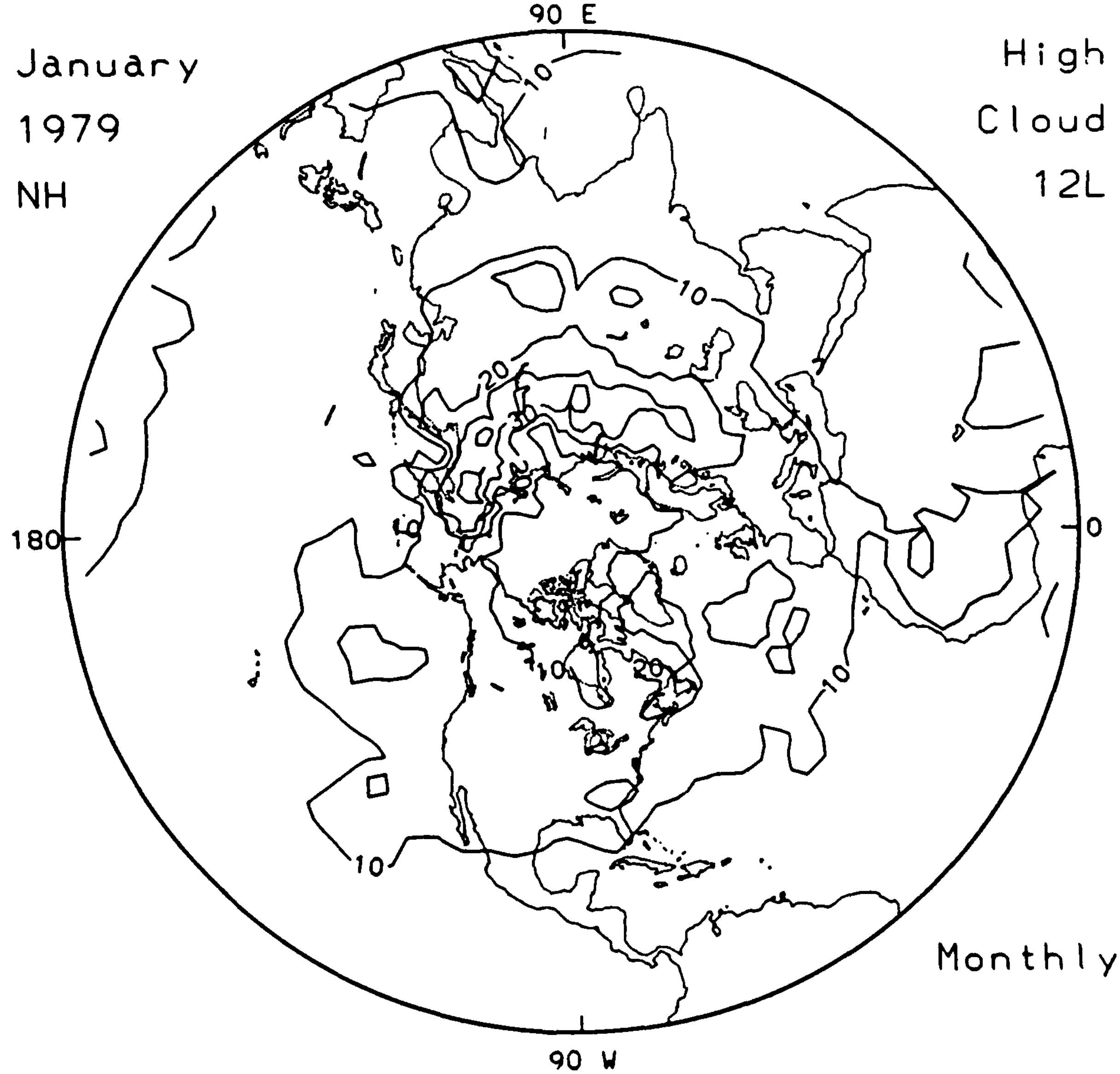

Fig. 19 The monthly average high cloud climatology for January 1979 at 12L.

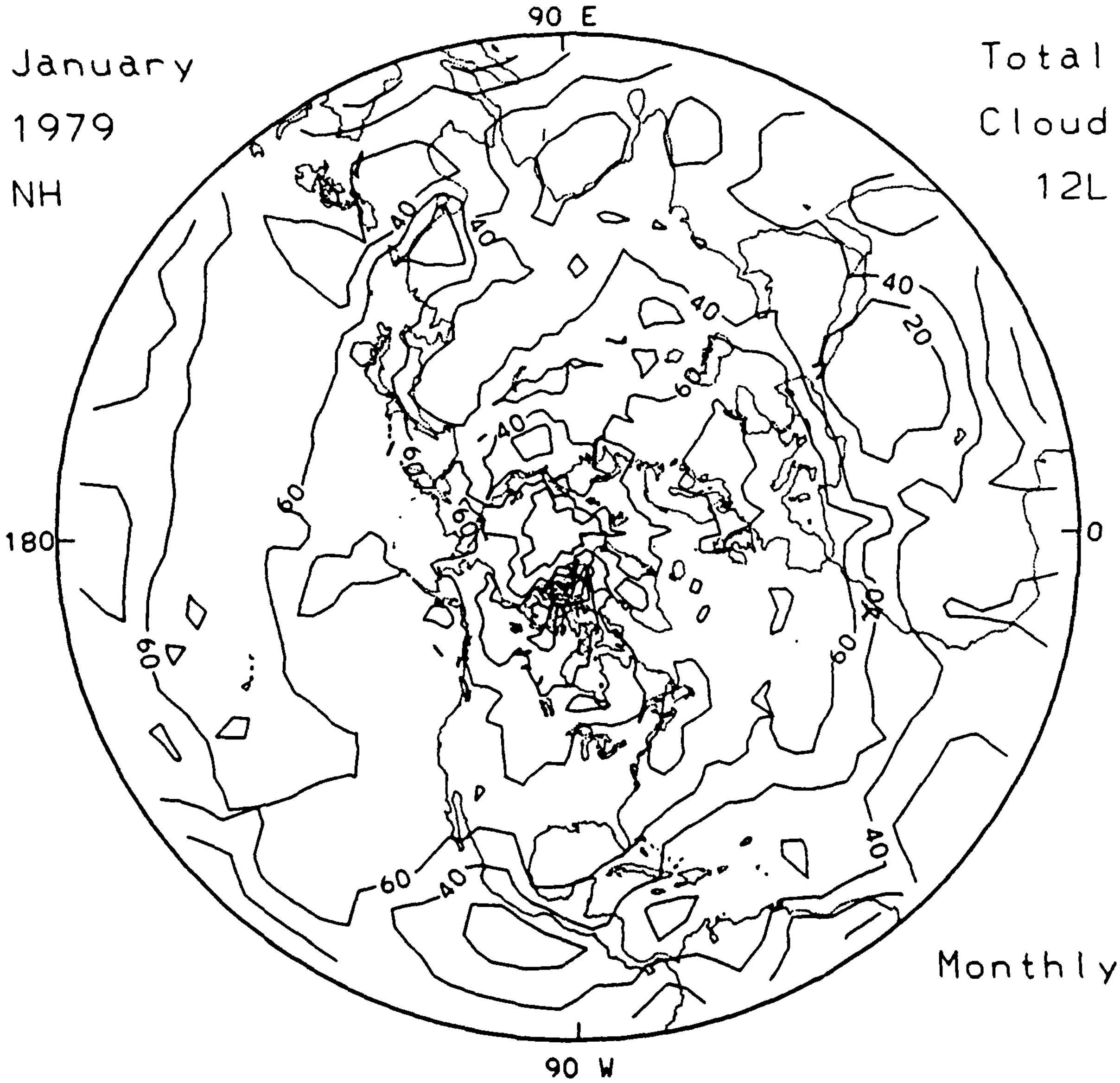

Fig. 20 The monthly average total cloud climatology for January 1979 at 12L.

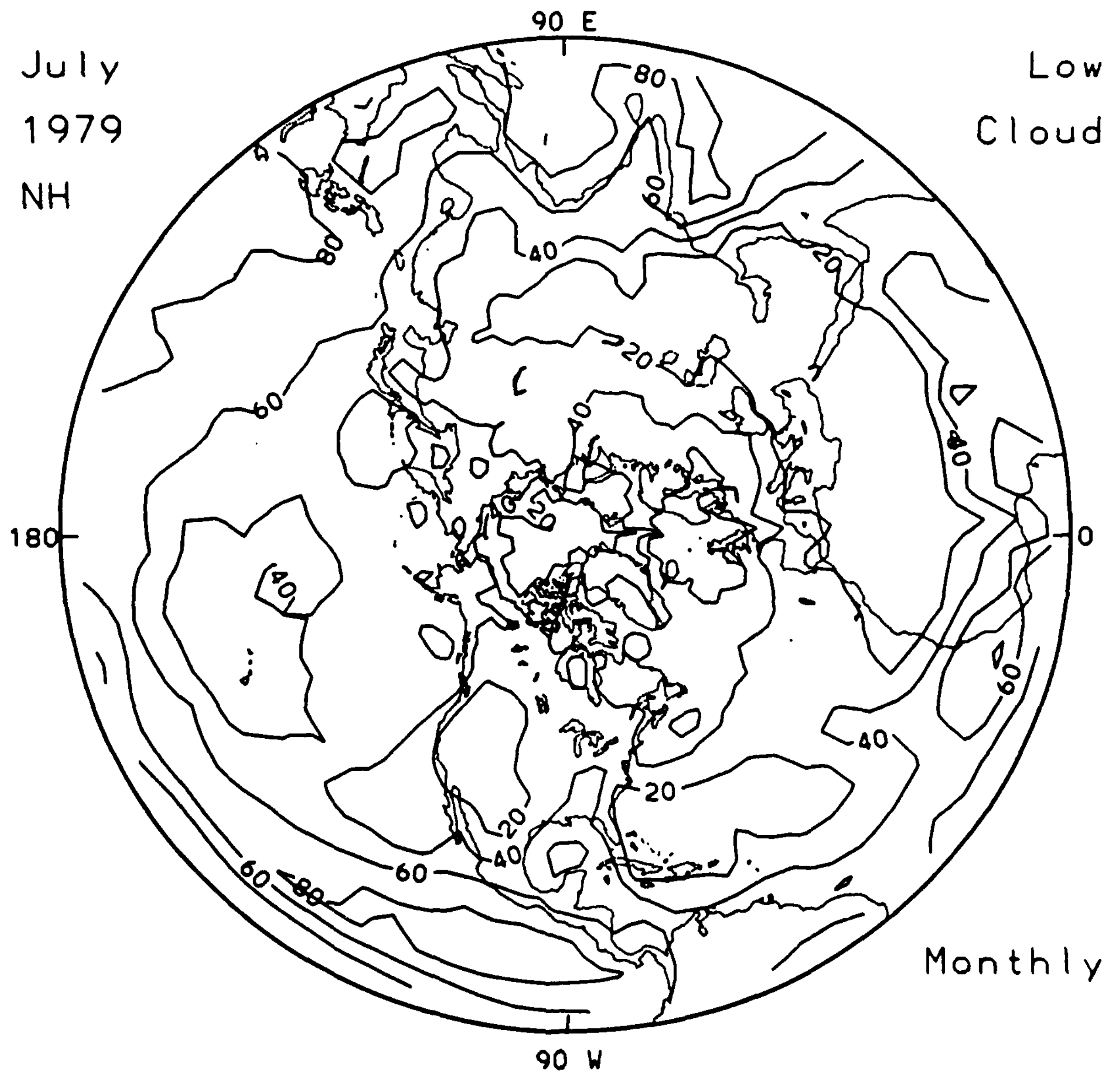

Fig. 21 The monthly average low cloud climatology for July 1979.

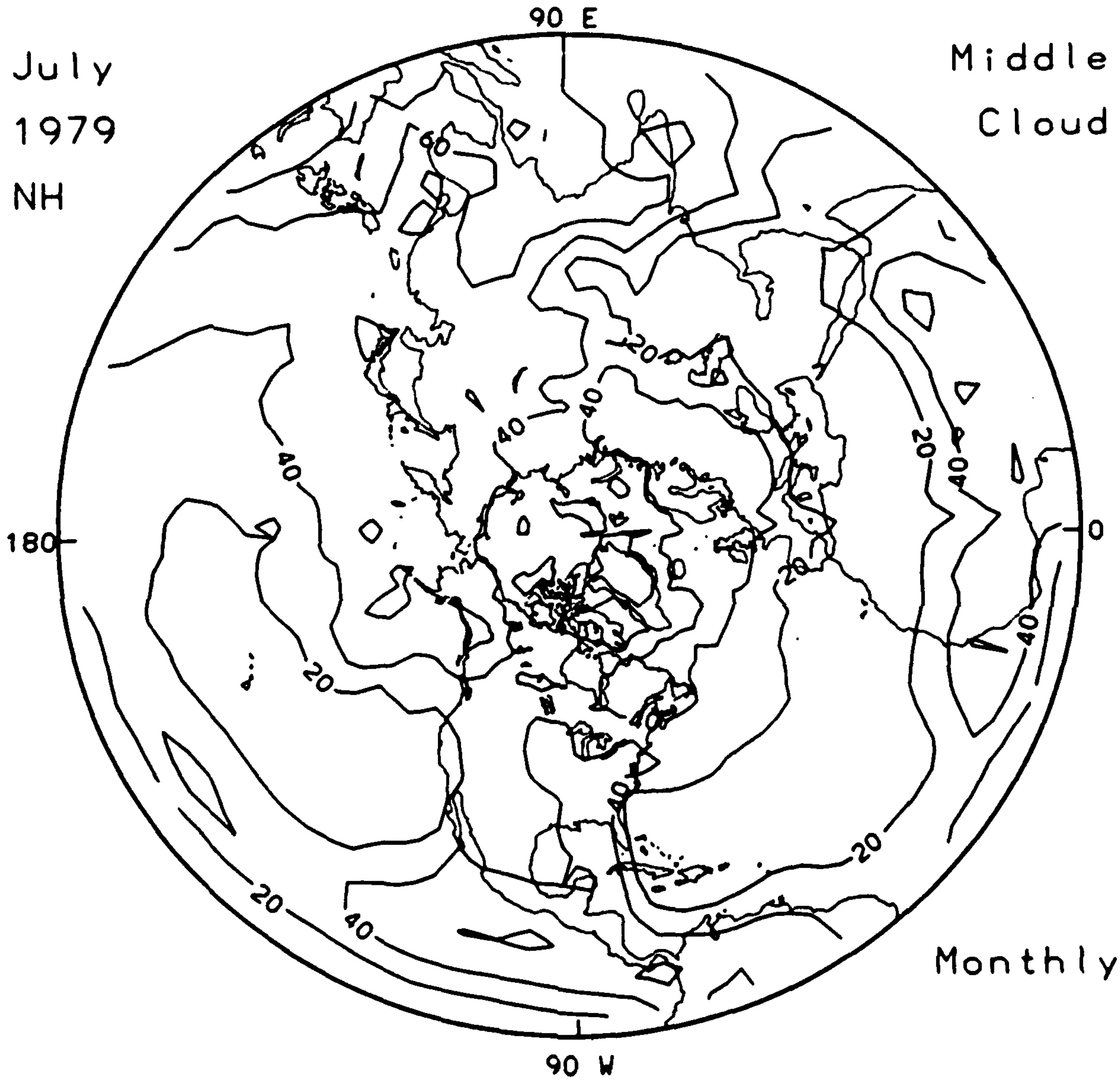

Fig. 22 The monthly average middle cloud climatology for July 1979.

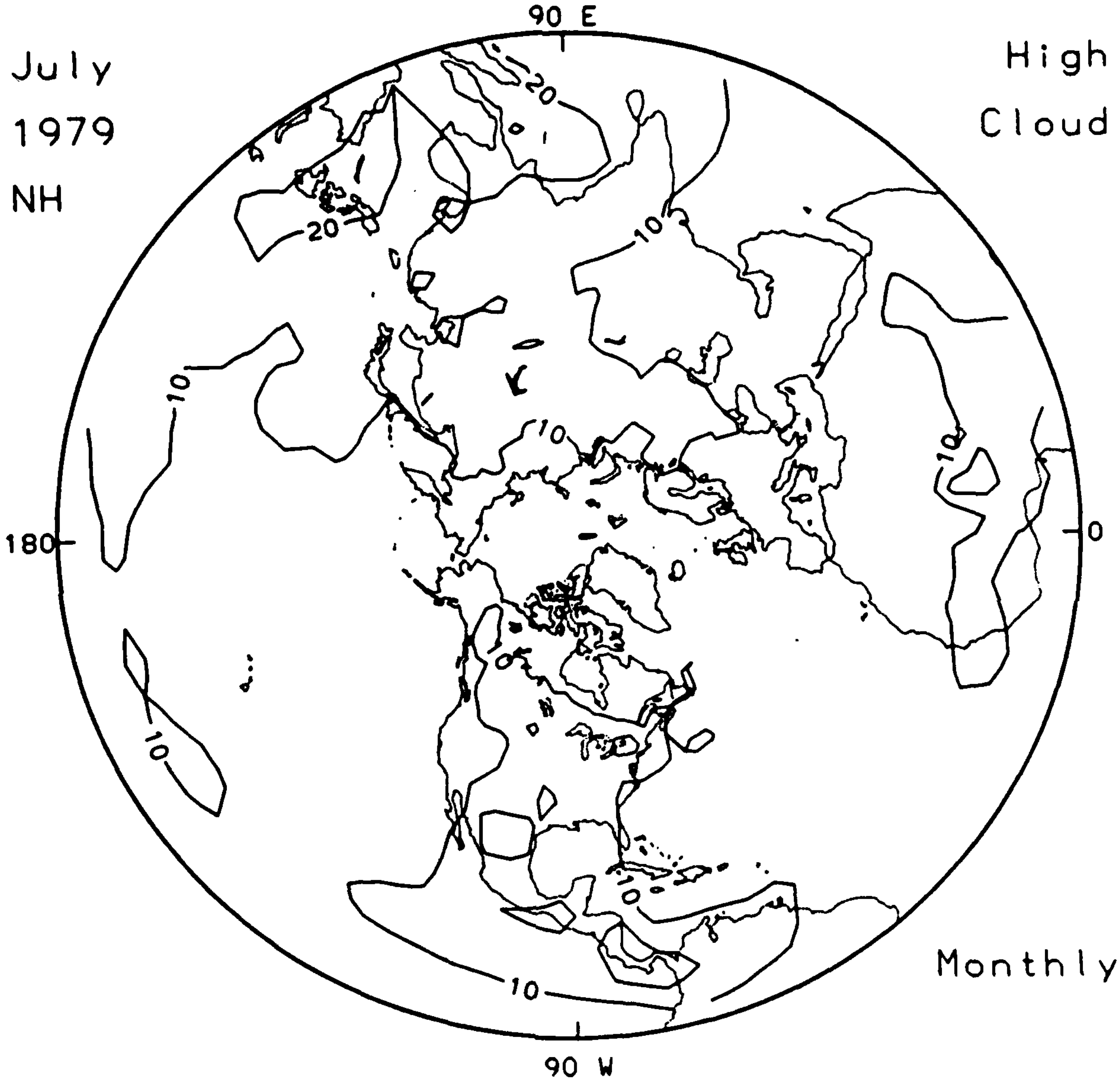

Fig. 23 The monthly average high cloud climatology for July 1979.

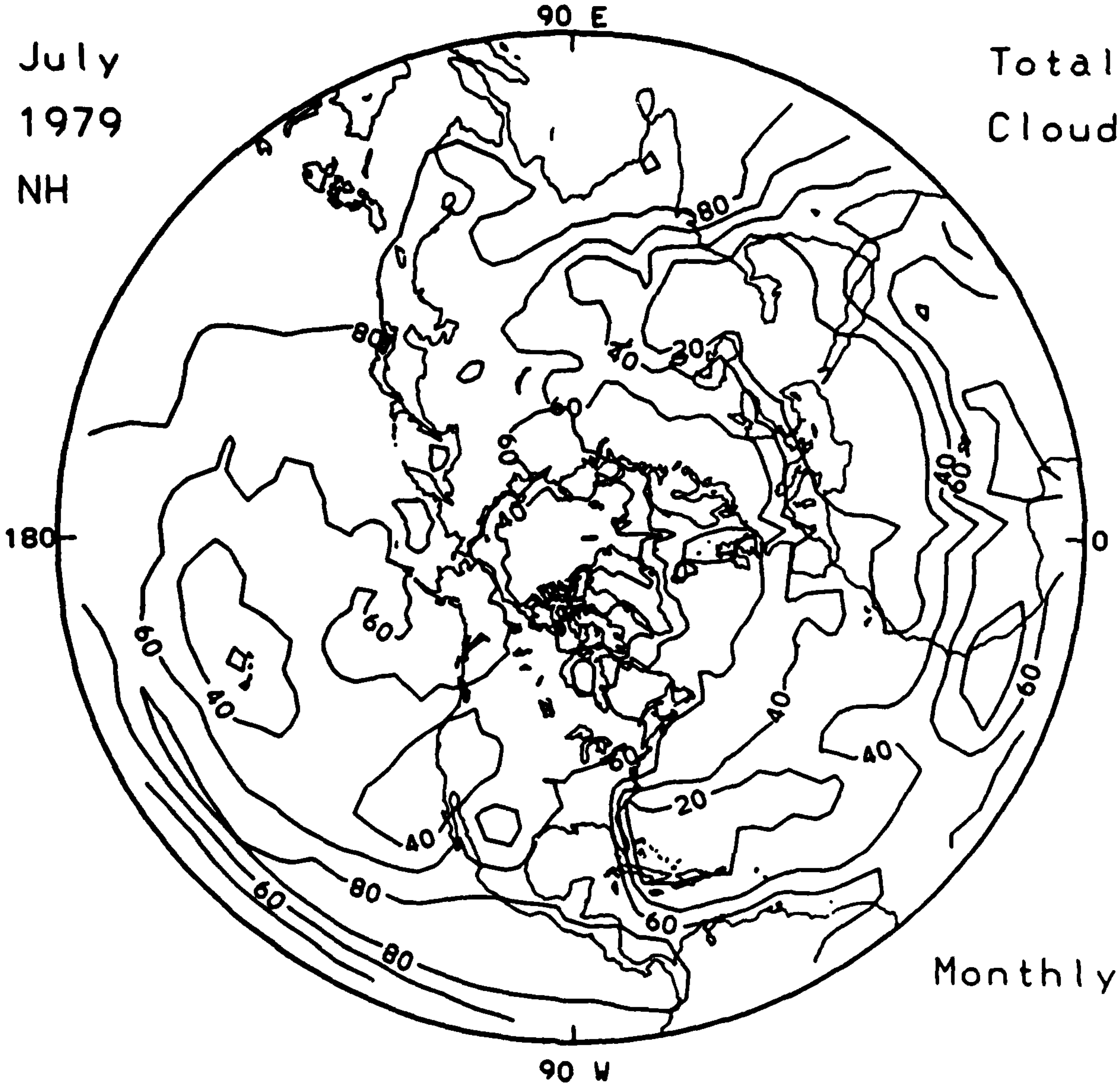

Fig. 24 The monthly average total cloud climatology for July 1979.

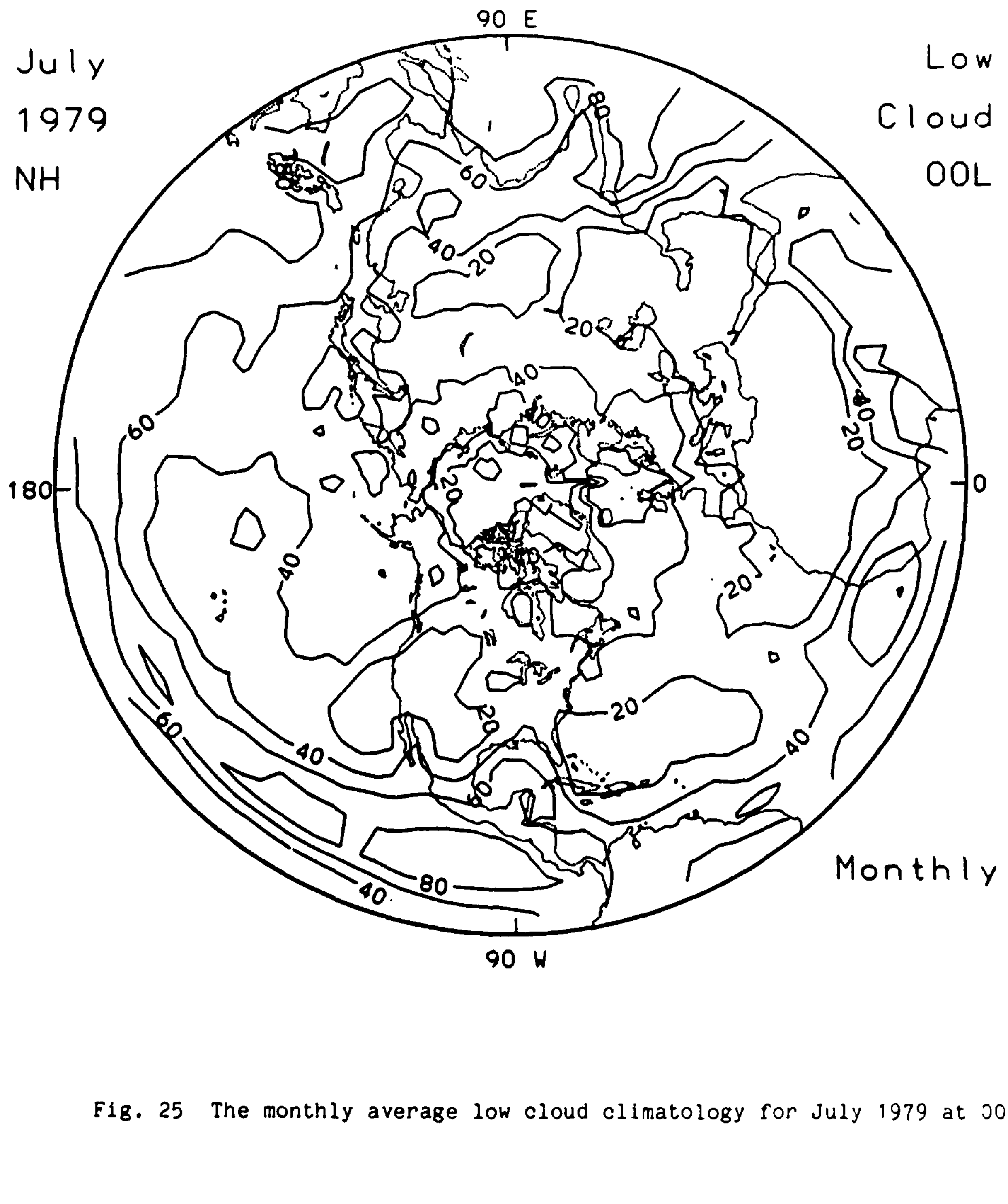

Fig. 25 The monthly average low cloud climatology for July 1979 at 00L.

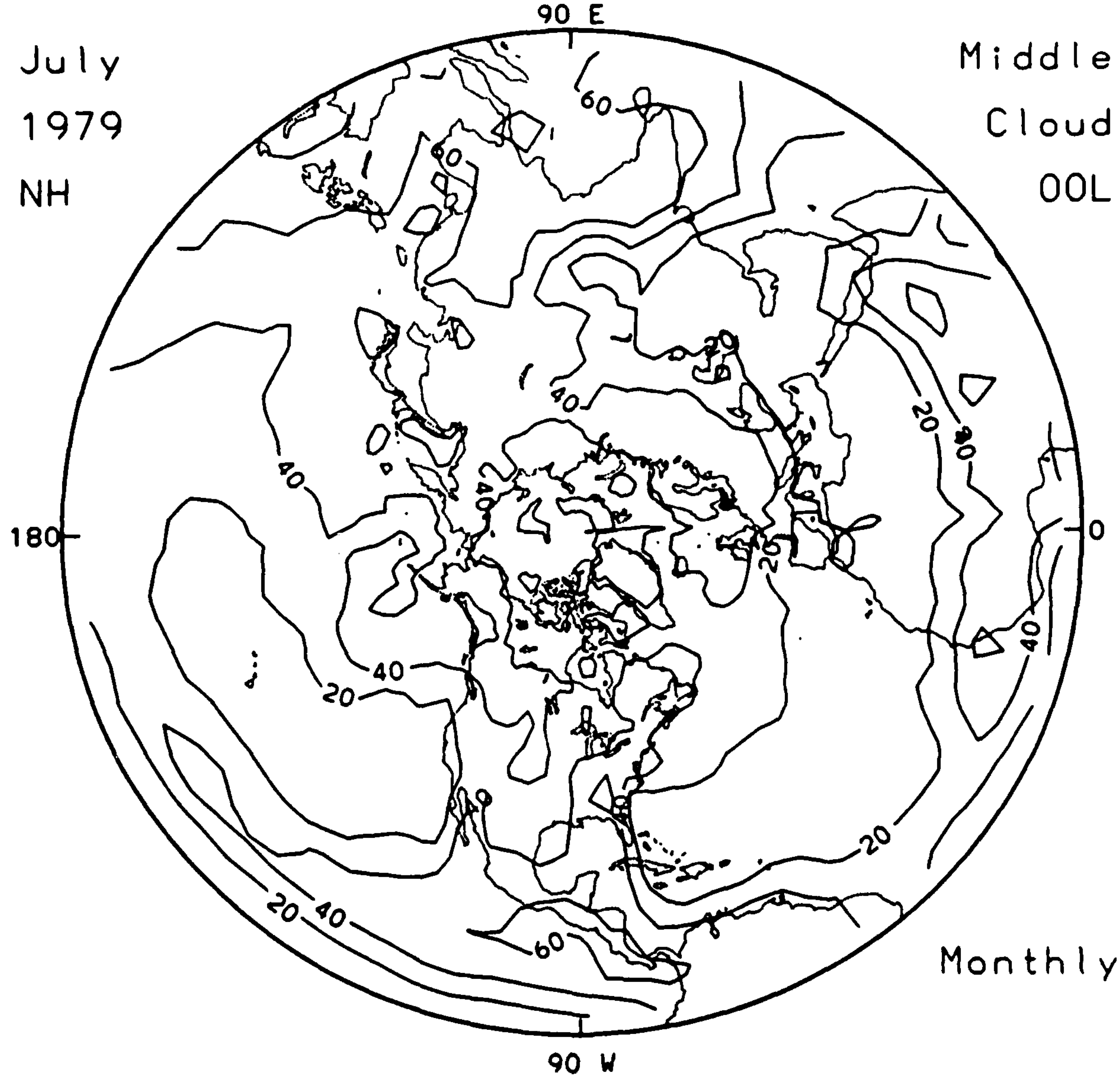

Fig. 26 The monthly average middle cloud climatology for July 1979 at 00L.

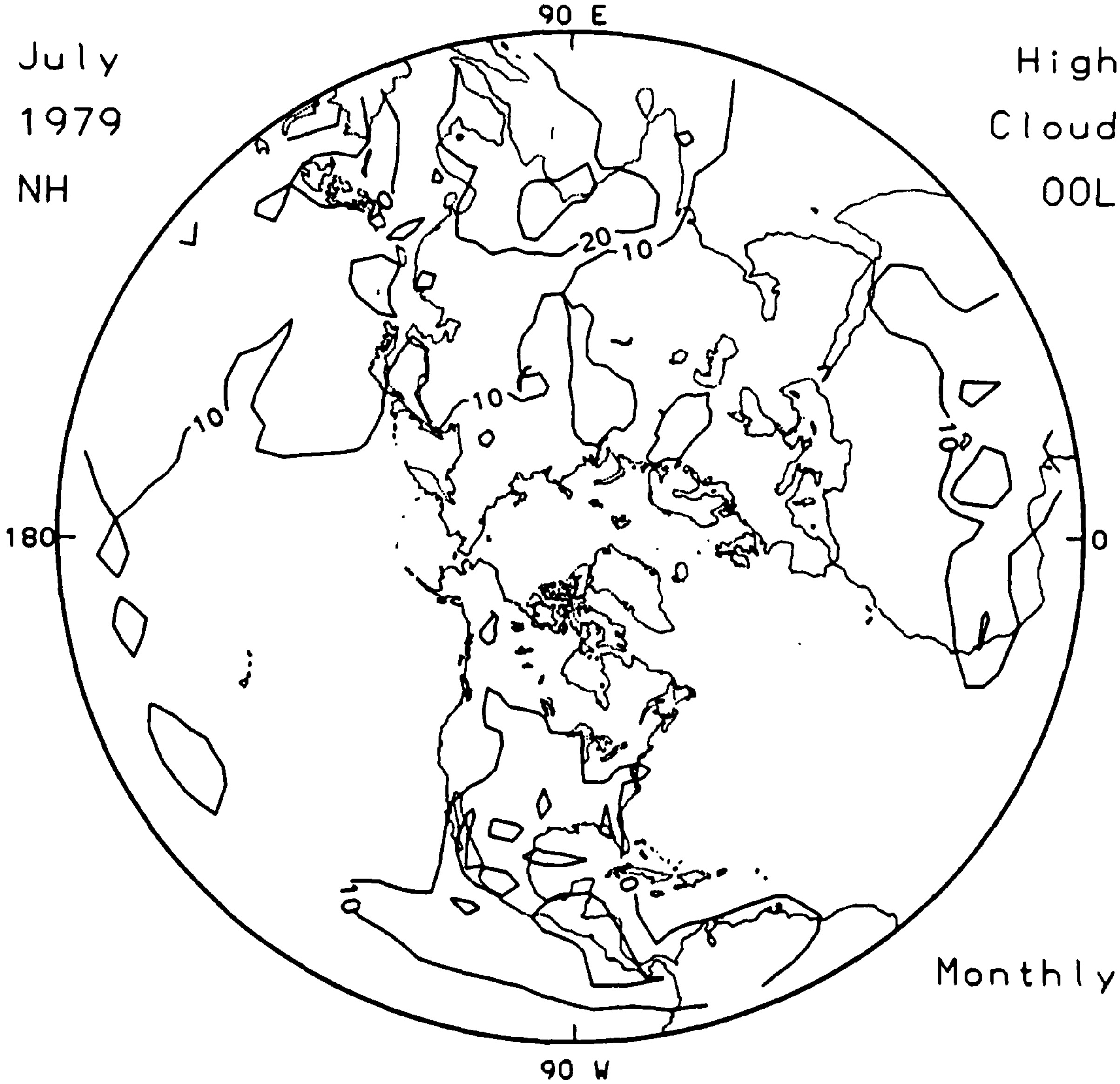

Fig. 27 The monthly average high cloud climatology for July 1979 at 00L.

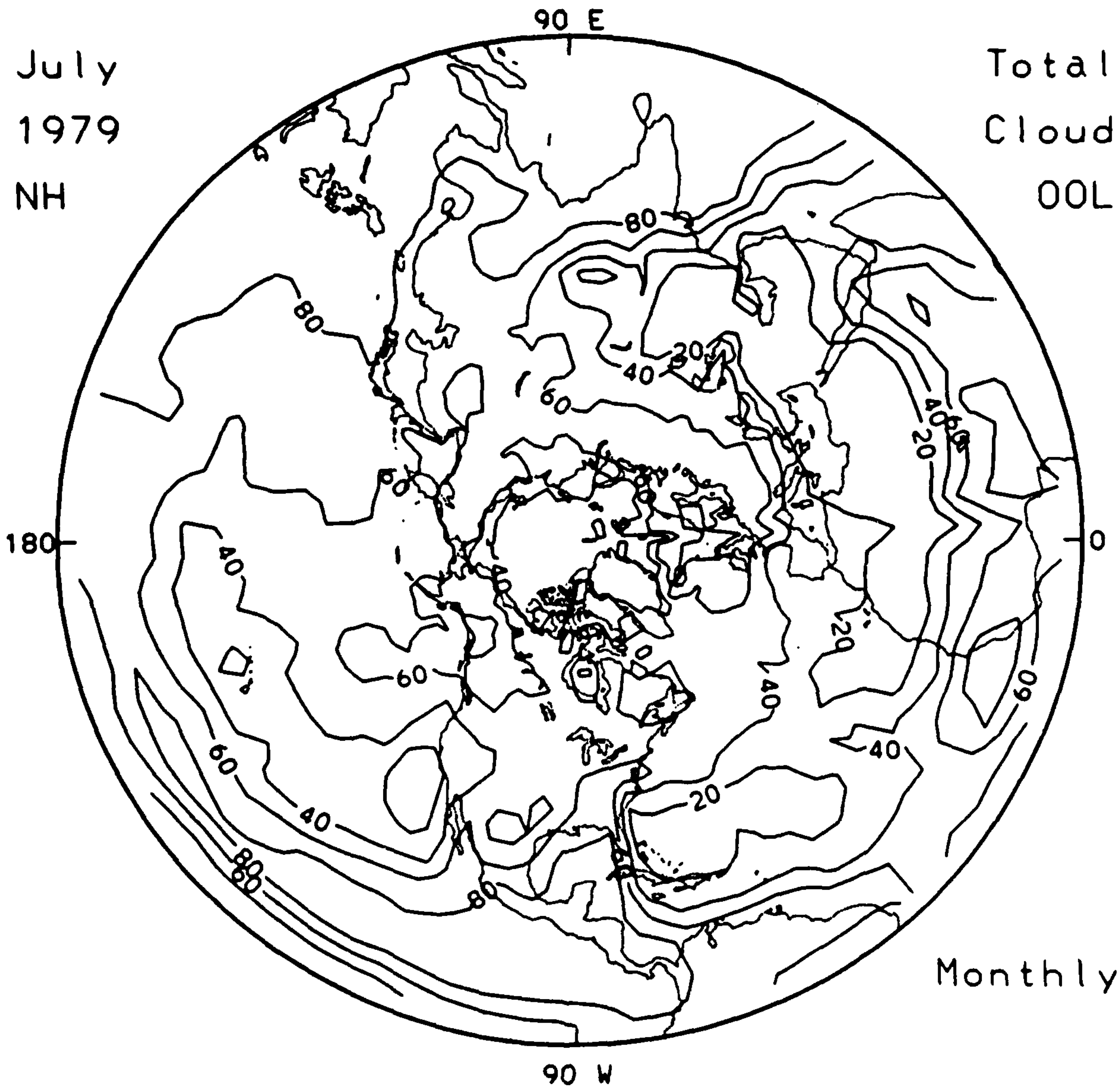

Fig. 28 The monthly average total cloud climatology for July 1979 at 00L.

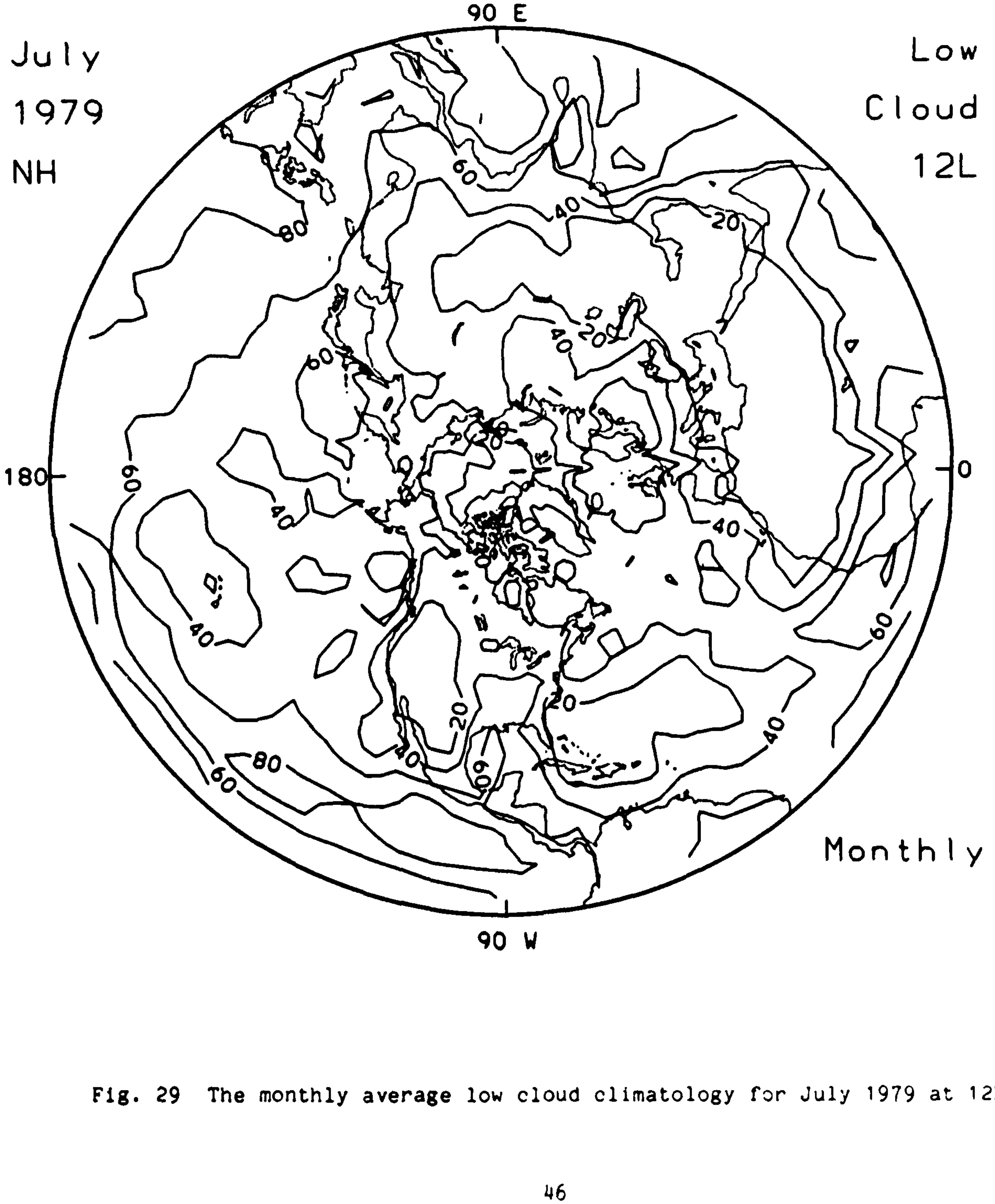

Fig. 29 The monthly average low cloud climatology for July 1979 at 12L.

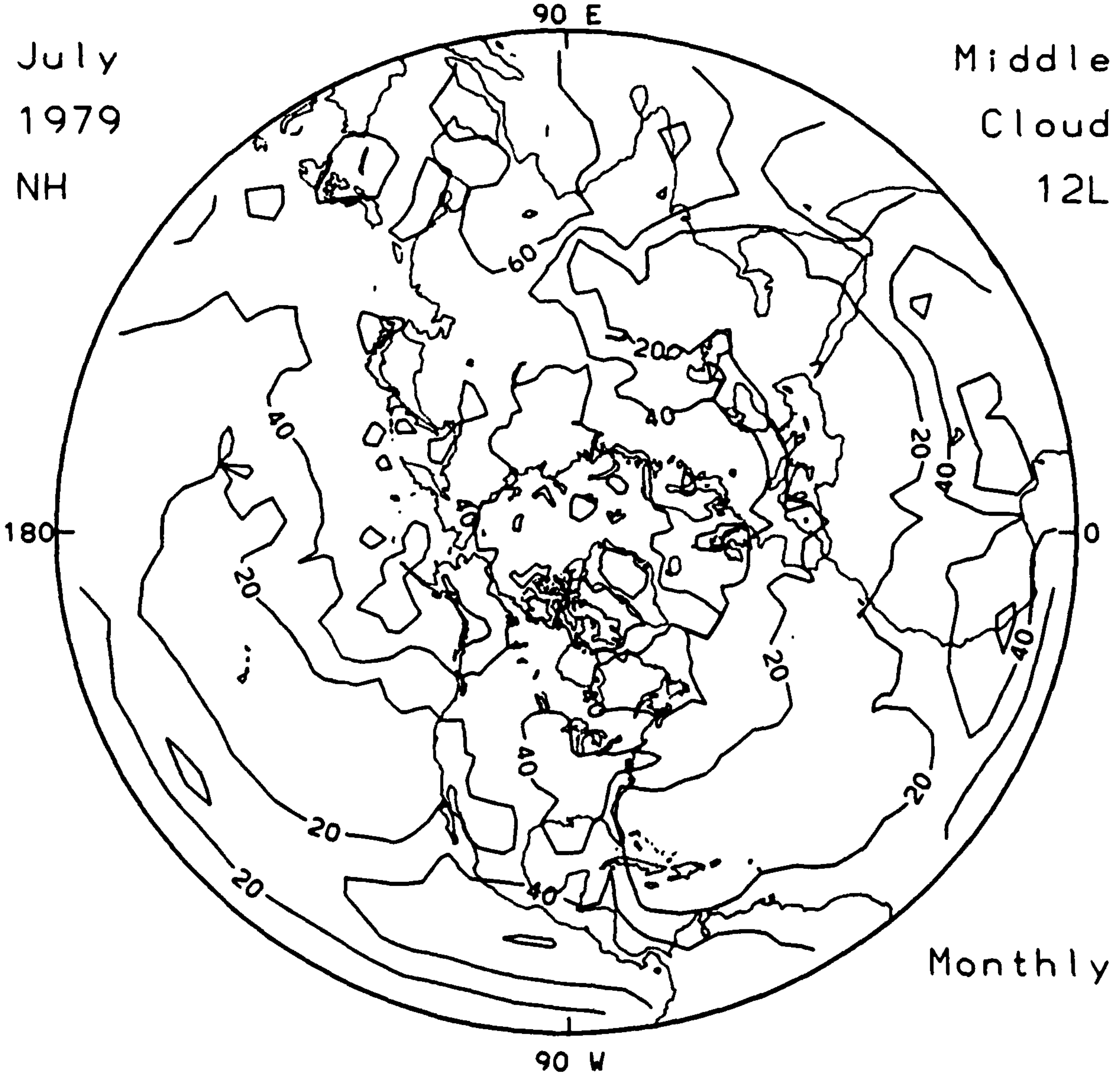

Fig. 30 The monthly average middle cloud climatology for July 1979 at 12L.

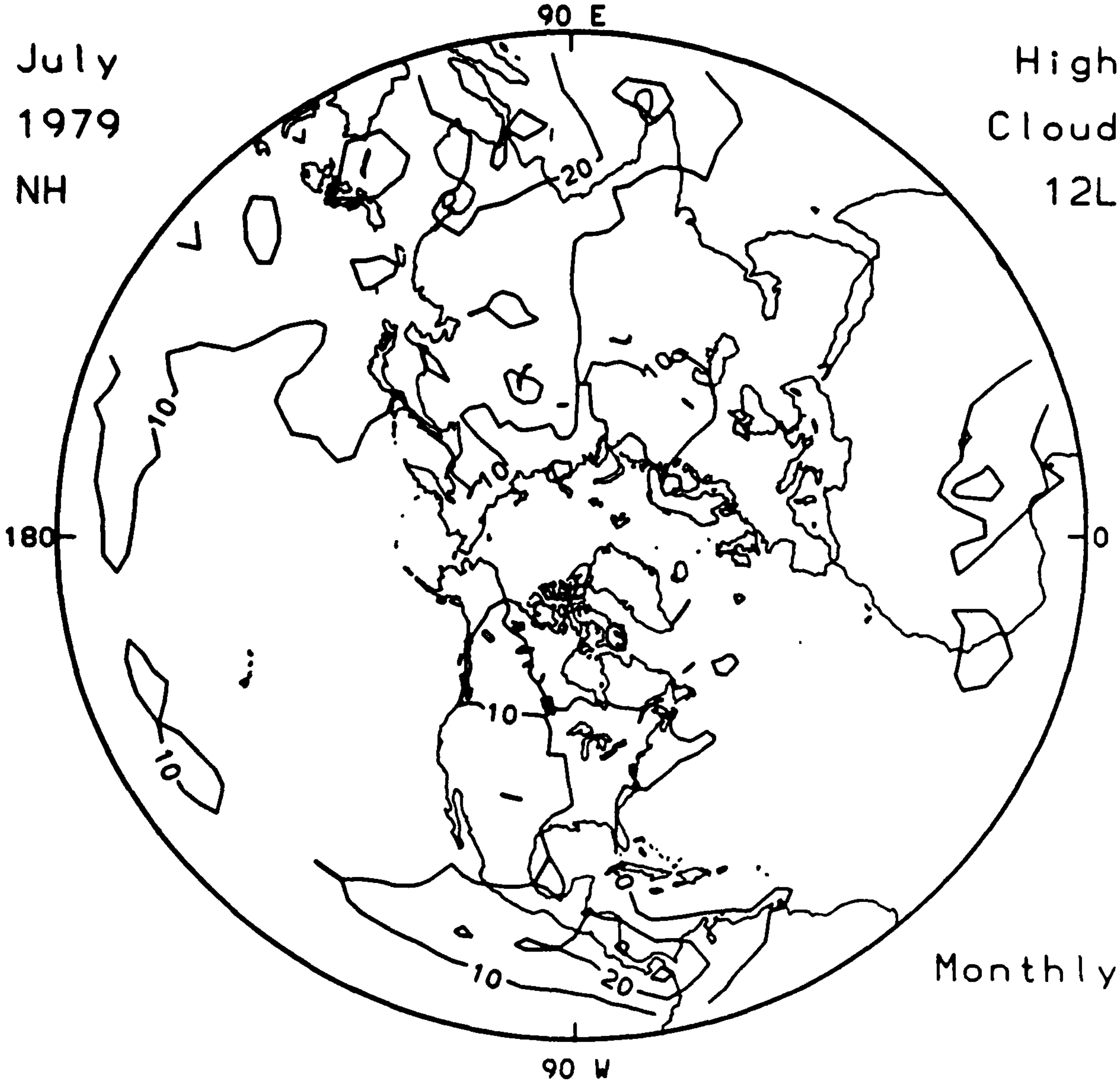

Fig. 31 The monthly average high cloud climatology for July 1979 at 12L.

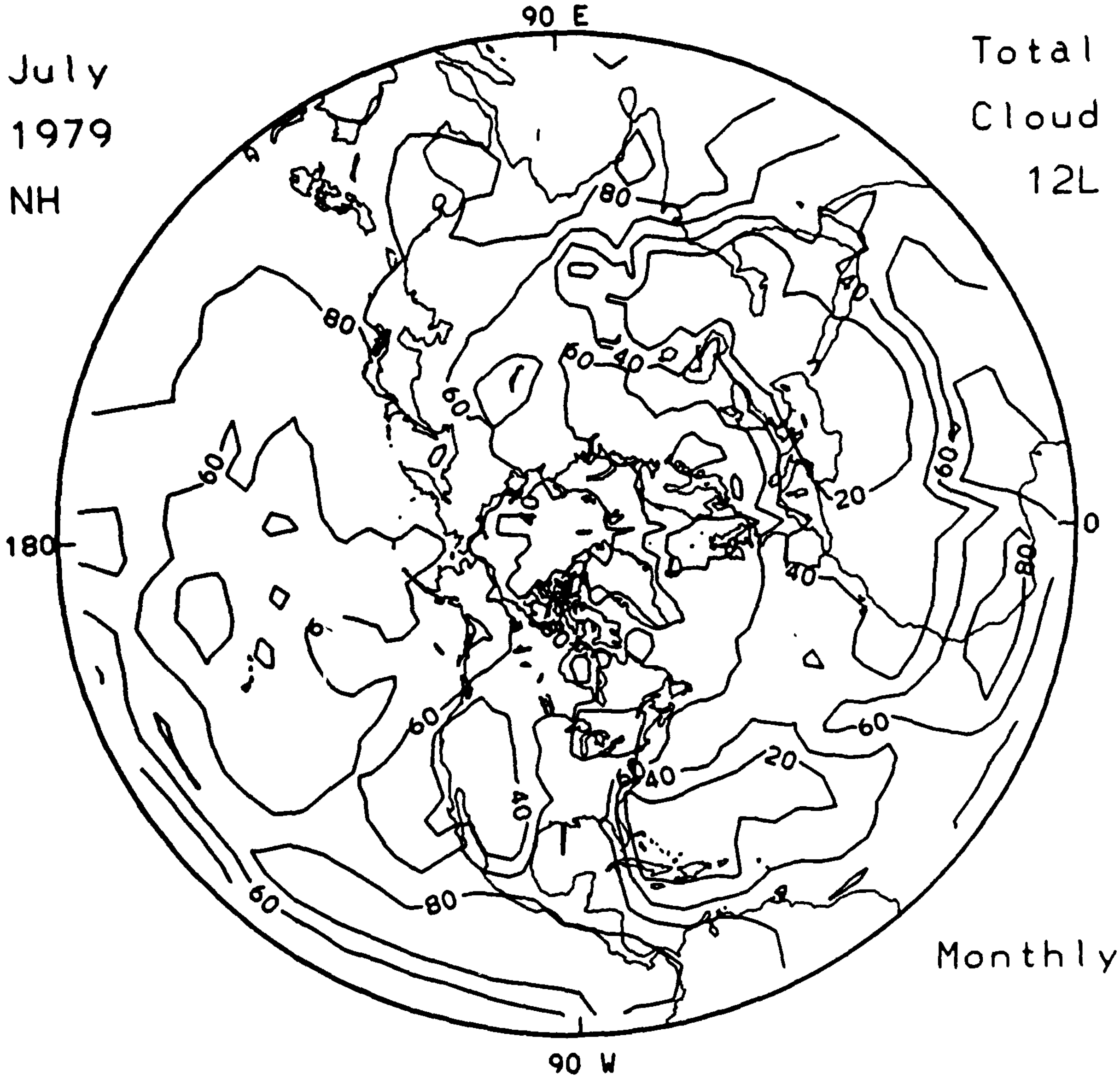

Fig. 32 The monthly average total cloud climatology for July 1979 at 12L.

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